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Why are medical research articles tweeted? The news value perspective

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Abstract
Counts of tweets mentioning research articles are potentially useful as social impact altmetric indicators, especially for health-related topics. One way to help understand what tweet counts indicate is to find factors that associate with the number of tweets received by articles. Using news value theory, this study examined six characteristics of research papers that may cause some articles to be more tweeted than others. For this, we manually coded 300 medical journal articles about COVID-19. A statistical analysis showed that all six factors that make articles more newsworthy according to news value theory (importance, controversy, elite nations, elite persons, scale, news prominence) associated with higher tweet counts. Since these factors are hypothesised to be general human news selection criteria, the results give new evidence that tweet counts may be indicators of general interest to members of society rather than measures of societal impact. This study also provides a new understanding of the strong positive relationship between news mentions and tweet counts for articles. Instead of news coverage attracting tweets or the other way round (journalists noticing highly tweeted articles and writing about them), the results are consistent with newsworthy characteristics of articles attracting both tweets and news mentions.

Keywords Twitter · COVID-19 · Altmetrics · News value

Introduction

Altmetrics, short for alternative metrics, report how often a research paper has been tweeted, cited, saved, or otherwise mentioned through social media, web reference management tools and other online platforms (Howard, 2012). Altmetrics were developed to quantitatively estimate the attention given to research articles on social media and other online platforms in the belief, partially verified by subsequent research, that this may give evidence of societal impact or early evidence of academic impact. Out of all altmetrics, reader counts from the social reference manager Mendeley and tweet counts

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from Twitter are the most common in all disciplines and data sources studied so far (Htoo & Na, 2017; Robinson-García et al., 2014; Thelwall et al., 2013; Zahedi et al., 2014). Mendeley reader counts have been shown to be an indicator of readership and particularly useful for assessing the early academic impact of research articles because Mendeley readers are mainly from academia (Mohammadi et al., 2015; Thelwall, 2018). In contrast, articles seem to be mostly (at least 55% in one sample) tweeted by non-academics (Mohammadi et al., 2018). Thus, whilst Mendeley reflects readership primarily by academics and partly by students, Twitter has the largest coverage of any altmetrics that might reflect non-academic interest. Nevertheless, it is still not clear what general conclusions can be drawn about research articles that are frequently tweeted.

One way to understand what the tweet counts of research papers reflect is to identify factors associating with greater numbers of tweets. In the early days of citation analysis, the idea of using citation counts as an indicator of the importance of research papers led to a series of inquiries into factors associated with higher citation counts. Studies have since revealed that citation counts are related to many factors, not all associated with "the quality" of the papers. Nevertheless, there was also evidence that citations were not randomly given to such an extent that the phenomenon of citation would lose its role as an indicator of research impact in many fields (van Raan, 2005). These studies have helped to understand citation behavior and facilitate practical applications of citation data in research evaluation. In altmetrics research, a few studies have explored factors associating with altmetric indicators. But the factors examined by previous studies were mostly the ones that were previously known to be associated citation counts. Since the process and people involved in tweeting and citing research papers are different, it is important to identify factors governing the selection of research papers by tweeters to understand what tweet counts reflect.

Twitter is a social platform that is also used to get and share news. Reflecting this, in 2016, Twitter moved from the "Social" to the "News" category on the Apple app store where it was the most popular app (Yahoo, 2016). The hashtag, tweet and retweet mechanisms of Twitter allow users to spread information of their choice to the extent that mainstream news media has lost its dominance of public opinion narratives (Buccoliero et al., 2020).

Nevertheless, Twitter can also support the mainstream media by sharing a story virally and allowing journalists to engage directly with their readers (Coyle, 2009). Most news outlets and journalists now have a presence on Twitter. In short, Twitter is a space where citizen journalism and professional journalism coexist.

From a media perspective, news value theories have been used to explain the news selection decisions of journalists as well as general public (Eilders, 2006). According to Galtung & Ruge (1965), when selecting news, journalists assign a news value to each event that depends on the intensity of the news factors associated with it. The higher the news value of the event, the better the chance of it being selected to appear in the news. Several studies have also investigated the selection of content and engagment on social media from a news value perspective (Araujo & van der Meer, 2020; García-Perdomo et al., 2018). Trilling et al. (2017) found that news factors can predict the number of shares for news articles on Twitter and Facebook, for example. Thus, the news value perspective may also explain why some research papers are frequently tweeted. This study therefore investigates whether news-related characteristics of research articles may cause some to be more tweeted than others. The research question is: *Do more newsworthy journal articles get tweeted more often, and by more tweeters?*

Literature review

News factors as general human selection criteria

News value research proposes that a number of key characteristics of events, usually called news factors, affect their newsworthiness. Galtung & Ruge (1965) proposed a system of twelve factors that affect the chances of an event being reported as news by the mass media. According to their theory, journalists tend to select events that satisfy those factors (*selection*). Once an event is selected as news, what makes it newsworthy according to the factors will be emphasized when reporting the event. This tends to distort reality towards these factors (*distortion*). In the chain of communication from event to reader or even in the reporting of information by people in general outside the context of journalism, the process of *selection* and *distortion* will be repeated at every link in the communication chain (replication) (Galtung & Ruge, 1965, p. 71).

All these factors seem likely to apply to tweeting and re-tweeting on Twitter, particularly because developments in news value research suggested that the same factors would be used by the public and journalists (Eilders, 2006). Schulz (1982, p. 149) went beyond the original theory by suggesting that news factors are "organizational criteria of collective perception which govern the media's as well as the individual's construction of reality". Eilders (2006) offered further explanations for news factors as general relevance indicators. For news factors such as "damage", the explanation was based on evolutionary theory and it claimed that "people assign relevance to things that mean a potential threat to someone's life or well-being" (Eilders, 2006, p. 14). From this perspective, events that are considered a potential threat to people would be of interest to the public and thus newsworthy. Similarly, for a few news factors, including "proximity", the explanation referred to general human psychological mechanisms which suggests that familiar subjects will be recognized and attended to because prior knowledge makes it easier for people to relate to them. Finally, for other news factors, including "relevance" and "reach" (i.e., the number of people affected by the event), the explanation was based on research on social cognition and sociology of knowledge. People assign relevance to events if society might be affected even if the individual is not directly affected (Eilders, 2006).

The importance of news factors as general human selection criteria has been applied to social media. Ziegele et al. (2014) used the rationale of news value theory to explain why some discussions are more interactive than others. They found that uncertainty, controversy, comprehensibility, negativity, and personalization can explain the amount of interaction in comments. Similarly, news factors can predict news sharing (Trilling et al., 2017) and the intensity of user engagement (Araujo & van der Meer, 2020) on social media. The present study is the first to investigate the extent to which news value theory can be used to explain audience sharing or selection of journal articles on Twitter. In this study, we first identified news factors proposed in the literature that are appropriate for the medical research papers of our chosen topic, COVID-19. We then investigated whether there is a difference, in terms of news factors, between highly tweeted articles and untweeted or poorly tweeted articles on the same topic, published in similar journals and in the same year.

News factors for medical research literature

Different news factors have been identified for different contexts. Medicine is the most popular science topic covered by the mass media (Clark & Illman, 2006) and previous studies have identified several news factors involved in journalists' selection of medical research articles. The following news factors were selected for this study due to their relevance to the topic and context of the study.

Importance

A topic must be important to make it in the news but, "the definition of *importance* has to be determined with regard to different systems of reference" (Badenschier & Wormer, 2012, p. 66). In the context of medical news, Burns et al. (1995) developed four criteria to measure the *importance* of medical articles based on "what the public needs to know" as a standard for reporting medical research in the news: (1) frequency of the disease or the size of the population affected by it; (2) immediacy with which the study's results could be applied; (3) definitiveness of the study's results; and (4) overall importance of the study as rated by reviewers. The validity of their measure of importance was verified as it was consistently a significant and positive predictor of all measures of newspaper reporting. Their findings suggested that important articles receive extensive, prominent, and timely newspaper coverage. In this study, we hypothesize the following:

Hypothesis 1 *Importance* positively associates with higher tweet counts.

Controversy

This has the greatest influence on the selection of science news (Badenschier & Wormer, 2012). For science news, controversy is "contrasting of differences in opinions" (Badenschier & Wormer, 2012). In the study by Stryker (2002), the *controversy* of medical journal articles was measured based on whether the paper supports or overturns existing evidence. Study results that explicitly overturned existing medical evidence were considered to be more controversial and more likely to receive news coverage. When assessed as a potential audience selection criterion for news articles by García-Perdomo et al. (2018), *controversy* was also a positive predictor of news sharing on Twitter. Similarly, when exploring criteria influencing user selection decisions for retweeting news on Twitter, Rudat et al. (2014) found that *controversy* was associated with high retweet rates. In this study, we hypothesize that:

Hypothesis 2 *Controversy* positively associates with higher tweet counts.

Elite nations

According to Galtung & Ruge (1965), news is elite-centered, in terms of nations or people: the more the event concerns elite nations, the more likely it will become a news item (see also: Chang, 1998). In science journalism, scientific events become news more easily when scientific elites are involved (Badenschier & Wormer, 2012). As for the media coverage of medical research, Bartlett et al. (2002; see also: Trilling et al., 2017)

found that medical studies from the UK were reported the most in British newspapers, followed by studies from other industrialised countries. Nevertheless, Stryker (2002), found that US origins were not important for media coverage. In this study, we hypothesize that:

Hypothesis 3 Scientific elite nation authorship positively associates with higher tweet counts.

Elite persons

Elite persons, or in some studies "prominence" or "influence", is one of the news factors repeatedly shown to affect the selection of news items (Eilders, 2006). In science journalism, Badenschier &Wormer (2012, p. 73) defined the news factor 'reference to elite persons' as "political, economic, cultural or scientific power of a person, group, or institution ranked by its position in the hierarchy". Generally, medical experts serve as an important source of information for the public during a pandemic (Leidecker-Sandmann et al., 2021). In this study, we hypothesize that:

Hypothesis 4 Scientific elite authorship positively associates with higher tweet counts.

Scale

One of the news factors proposed by Galtung & Ruge (1965) is called *threshold*, which refers to the level that an event must reach in terms of scale to become news (called superlativeness in linguistics: Bednarek & Caple, 2012). In science news, huge international science projects such as the Conseil Européen pour la Recherche Nucléaire (CERN) receive considerable media attention, for example. The scale of an investigation is often dictated by the scale of the collaborations involved. In this study, we hypothesize that:

Hypothesis 5a The scale of the study, in terms of the number of countries collaborating, positively associates with higher tweet counts.

Hypothesis 5b The scale of the study, in terms of the number of researchers collaborating, positively associates with higher tweet counts.

News prominence

In the news selection process, the news value assigned to an event is reflected in the degree of prominence given to the event in the media. Using four measures of news prominence, Schulz (1982) discovered that news prominence affects the audience's awareness of an event. The role of media in creating public awareness of science is well reported in the literature (Chapman et al., 2014). Even in the age of social media, mobile users are likely to directly consult traditional news organizations (Van Slooten et al., 2013). Thus we hypothesize that:

Hypothesis 6a Mass media news prominence positively associates with higher tweet counts.

In addition, news prominence is known to have a moderating effect. Eilders (2006) stated that news factors affect audience selection through mass media prominence. Thus, we examine the moderating effect of news prominence on the relationship between other news factors and tweet counts. We hypothesize that:

Hypothesis 6b News prominence moderates the relationship between news factors and tweet counts.

Method

Data collection

Twitter has been claimed to be the most popular platform for healthcare communication (Pershad et al., 2018), and health and biomedical topics have been addressed by many altmetric studies (Mohammadi et al., 2020). For this study the topic COVID-19 was chosen as the most common current health topic, allowing the most data to be collected, and supporting a more statistically powerful study. For this, all articles with "COVID-19" in their titles, abstracts or keywords, under the subject area Medicine, published in 2020 and document type "article", were retrieved from Scopus via its Applications Programming Interface (API). To minimize the influence of journal reputation, we then selected articles from the same impact quartile, Q1, published between January and October 2020, as data collection was done in December 2020. At this stage, there were 2393 articles from Q1 medical journals in the dataset. Next, by matching article DOIs, tweet counts (or tweeter counts) and news mention counts of the articles were collected from the Altmetric.com API. For each paper, each tweet represents a unique tweeter in the data provided by Altmetric.com. Therefore, tweet counts for each paper are the same as tweeter counts.

When choosing a sample of papers out of a total of 2393 for manual content analysis, we selected the 150 most tweeted and 150 least tweeted articles to enable higher statistical power. As the distribution of tweet counts is very skewed, most articles in a random sample would have few tweets, giving low statistical power for any test. Although automated content analysis has been tried with relatively large sample sizes when investigating news value and news factors, most news value studies rely on manual content analysis as there are factors, such as controversy, that cannot reliably be automatically detected. And due to the time-consuming nature of manual content analysis, sample sizes are often small. When choosing the sample size for this study, we considered the sample size of 95 research articles ($N=95$) in a previous similar study by Stryker (2002), which is the only prior study of the newsworthiness of medical research articles. We increased the sample size to 300 articles to generate more powerful conclusions. For the 150 most tweeted articles in our dataset, the tweet counts range from 425 to 37,329. The 150 least tweeted articles received no tweets or one tweet.

Measures

Importance

To measure the importance of COVID-19 medical research papers in this study, we used two criteria adapted from Burns et al. (1995): *immediacy* and *definitiveness*.

Here, *immediacy* refers to the speed with which a study's results can contribute to controlling the outbreak. Based on the global research roadmap set out for COVID-19 by the World Health Organization (2020), we identified research supporting the following areas as immediate needs, coding them "1" (otherwise "0").

- Rapid point of care diagnostics (symptoms/diagnostics/characteristics)
- Adjunctive and supportive therapies and investigational therapeutics (treatment)
- Personal protective equipment, other infection prevention and control measures to protect health care workers and the community from transmission (prevention and control)
- Vaccines (vaccine)
- Transmission dynamics such as person-to-person transmission, asymptomatic infection, environmental factors relating to transmission (transmission)
- Risk groups, conditions that make the disease more severe, mortality, cause of death (risk)

Although the following topics are also important, they were not classified as immediate needs in this study.

- Epidemiology (epidemiological) – transmission, illness or death from disease nationally, regionally and globally
- Understanding the virus—natural history virus, etc. (virus)
- Resource allocation and use, service delivery, policy, awareness, recovery (management)
- Impact of COVID-19 (impact)

For the criteria *definitiveness*, we assessed the *scientific tentativeness* of a study (Flemming et al., 2017), based on the use of randomization, sample size and the existence of suitable control groups. Articles were coded '1' if they used randomization and control groups with a minimum sample size of 100, otherwise '0'.

We called the total of *immediacy* and *definitiveness* the *importance score* of the article: 0, 1, or 2. Based on their titles and abstracts, all the articles in the sample were checked by two coders independently for characteristics that were believed to describe *immediacy* and *definitiveness* according to the operationalizations mentioned above. The first coder was one of the authors from this study and the second was a research assistant, who was, at the time of this study, a final year Communication Studies undergraduate from the same institution. Interrater reliability, estimated using Cohen's kappa, for *immediacy* was 0.52, for *definitiveness* was 0.93 and for the overall *importance score* was 0.60, all of which are sufficiently high to use the results.

Controversy

In the absence of a cure, the management of COVID-19 mainly involves infection prevention and control measures, supportive therapies and proposed drugs whose benefits, efficacy or safety are often contested or portrayed as controversial in the news or in the literature. While controversies about the efficacy of hydroxychloroquine were widely publicized, the efficacy of other treatments are equally arguable but not widely reported or discussed. As medical controversies are considered part of and often linked to scientific uncertainty (Dixon & Clarke, 2012; Friedman et al., 2012), in this study, we regarded all treatments as

controversial, along with the widely known controversial public health interventions and countermeasures. Based on this operationalization, we coded the papers in our sample on the topics such as the following as controversial.

Disputed public health interventions and countermeasures:

- Social or physical distancing interventions including closure of schools or workplaces, restrictions on mass gatherings and public events, including lockdowns
- Wearing face masks
- Vaccines

Treatments:

- Hydroxychloroquine or chloroquine
- Vitamin D supplements
- Prone positioning
- Azithromycin
- Plasma transfusion

Examples of controversial articles include "Treatment of 5 Critically Ill Patients with COVID-19 with Convalescent Plasma" (Shen et al., 2020) and "Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: a systematic review and meta-analysis" (Chu et al., 2020). Interrater reliability, estimated using Cohen's kappa, for this variable was 0.76.

Elite nations

In this study, *elite nations* are countries with high scientific influence, as estimated by the highest concentration of highly cited researchers in the country. Articles were coded "1" if one of the authors is from one of the ten countries with the highest proportions of highly cited researchers (Nielsen & Andersen, 2021).

1. Netherlands
2. England
3. Scotland
4. Switzerland
5. Canada
6. United States
7. Australia
8. Denmark
9. New Zealand
10. Belgium

Elite persons

In the special theory of news values for science news, reference to elite persons is defined as "political economic cultural or scientific power of a person, group or institution ranked by its power/position in the hierarchy" (Badenschier & Wormer, 2012). In this study, two measures of elite persons were used: elite persons—medical, and elite

persons—COVID-19. Elite persons—medical refers to authors from the top 30 medical institutions ranked by saliency (Microsoft Academic, 2021b) (Appendix 1). Elite persons—COVID-19 refers to authors from the top 30 institutions in Coronavirus research ranked by saliency (Microsoft Academic, 2021a), according to Microsoft Academic (Appendix 2). Articles were coded '1' for each measure if the study was done by at least one author from these institutions, otherwise '0'. Here, elite persons are equated with elite institutions on the basis that successful researchers often move to, or emerge from, prestigious institutions.

Scale

Scale refers to the scale of the research study. We used two measures of scale in this study: the number of countries and the number of researchers collaborating on the study.

News prominence

Schulz (1982) used four news prominence/value indicators for television news and newspaper articles: (1) position of news story in the programme, (2) length of the story, (3) presentation of still pictures or motion pictures, (4) the frequency of coverage (number of news stories per event). The present study used the frequency of coverage, which is measured by the number of times a research article appeared in the news. This data was collected from Altmetric.com, where it is called news mention count. This figure reflects the media sources indexed by Altmetric.com.

Analysis

As the purpose of this study is to examine if the presence of the news factors influence how research papers are tweeted, we tested the difference in mean tweet counts between articles with news factors and articles without. Thus, the dependent variable for all the analyses was the number of tweets (tweet count) about a given journal article. As the dependent variable was highly skewed, Mann–Whitney U tests or Kruskal–Wallis H tests were used for categorical independent variables when testing the difference in mean tweet counts. For continuous independent variables, Spearman's Rho was used to test the correlation between tweet counts and news factors. Since these tests are all nonparametric, it does not matter that the tweet counts are extreme values only (0, 1, or at least 425). Nevertheless, the tests primarily check the difference between the low and high tweet counts and the relationship may be different for moderate tweet counts.

To investigate the moderating effect of news prominence on the relationship between news factors and tweet counts, hierarchical multiple linear regression was selected. When choosing a suitable regression model in citation and altmetrics studies, as the data is skewed and the variance is greater than the mean, some altmetrics studies have used Negative Binomial Multiple Regression (NBMR) (Pandian et al., 2019). However, Thelwall & Wilson (2014) showed that Ordinary Least Squares (OLS) regression, after log-transformation, is the most suitable regression strategy for citation and altmetric data as it takes into account very high values, which are typical for skewed distributions. After testing both NBMR and OLS regression with log-transformed tweet counts, OLS regression with log-transformed tweet counts was selected because it provided a better model, based on lower AIC (Akaike Information Criteria) and BIC (Bayesian

Information Criterion) values. The OLS normally distributed residuals assumption is not violated by the absence of tweet counts between 2 and 424 but again the results primarily apply to the difference between low and high tweet counts.

A hierarchical multiple linear regression was conducted for each news factor with log-transformed tweet counts ln(1 + tweet count) as the dependent variable. In the first step, two variables, a news factor and news mention counts, were entered as independent predictors of tweet counts. Since the news mention count was a continuous variable, it was mean-centered to make the result more interpretable, and to avoid multicollinearity when testing the interaction effect. In the second step, the moderating or interaction effect of news prominence was tested by entering the product of the news factor and mean-centred news mention counts as an additional predictor.

Results and discussion

The results of Kruskal–Wallis H test and Mann–Whitney U tests in Table 1 show that all news factors significantly associate with higher tweet counts for research papers, supporting H1 through H4.

Table 1 Comparison test results for articles with and without news factors

Importance score	**N(%)**	**Mean rank**	**Kruskal–Wallis H Test χ^2**
0	88 (29.33%)	98.33	65.83**
1	190 (63.33%)	163.63	
2	22 (7.33%)	245.77	
Controversy			**Mann–Whitney U Test**
Articles without controversy	214 (71.33%)	137.20	6356.00**
Articles with controversy	86 (28.67%)	183.59	
Elite nations			
Articles from non-elite nations	140 (46.67%)	125.54	7706.00**
Articles from elite nations	160 (53.33%)	172.34	
Elite Persons—Medical			
Articles from top medical institutions	81 (27%)	191.71	5531.50**
Articles from other institutions	219 (73%)	135.26	
Elite persons—COVID-19			
Articles from top coronavirus research institutions	83 (27.67%)	203.02	4646.00*
Articles from other institutions	217 (72.33%)	130.41	

$p < 0.01$**, $p < 0.05$*

Importance

About 71% of the papers have an importance score of 1 or 2, and the higher the score, the higher the tweet counts. This is in line with the findings by Burns et al. (1995) which indicated that research articles considered important to public received extensive news coverage. But compared to how newspapers preferentially cover medical research with weaker methodologies (Selvaraj et al., 2014), audience selection of research papers on Twitter seems to be associated more with superior quality because papers with an importance score of 2 used randomization and control groups. In medical research, randomized controlled trials are the gold standard for testing the safety and efficacy of drugs or therapies (Röhrig et al., 2009). This finding is also in line with the results of a study by Kunze et al. (2020) as they found that research with stronger methodologies and limited study bias tended to have much higher altmetric attention scores, which includes tweet counts. These findings lend more authority to tweet counts as credible indicators. This study measured importance more comprehensively than Kunze et al. (2020) and verified for the first time that it was a significant factor in the audience selection of research papers on Twitter.

Controversy

About 29% of the articles in our sample scored 1 for *controversy* and a Mann–Whitney U test indicated that they attracted significantly higher tweet counts (Table 1). Controversy has been validated as a selection criterion by journalists for news coverage of medical research papers (Stryker, 2002) and for the public sharing news articles on Twitter (García-Perdomo et al., 2018; Trilling et al., 2017). This study contributes new evidence that controversy is also an audience selection criterion for tweeting research papers.

Elite nations & elite persons

About 53% of the sampled articles had at least one elite nation author and a Mann–Whitney U test indicated that these articles had significantly higher tweet counts (Table 1). We further analysed if those articles had higher importance scores or were more controversial. Both Kruskal–Wallis Test and Mann–Whitney U Test results in Table 2 were not

Table 2 Comparison test results for articles with and without Elite nations factor

Importance score	*N* (%)	Mean rank	Kruskal–Wallis H Test $\chi 2$
0	88 (29.33%)	147.20	3.60
1	190 (63.33%)	148.66	
2	22 (7.33%)	179.59	
Controversy			Mann–Whitney U Test
Articles without controversy	214 (71.33%)	148.30	8732.00
Articles with controversy	86 (28.67%)	155.97	

Table 3 Descriptive statistics of author and country counts in two groups of papers

	Papers with the most tweets (N = 150)		Papers with the least tweets (N = 150)	
	Author count	Country count	Author count	Country count
Minimum	2	1	1	1
Maximum	1242	80	49	4
Mean	31.74	2.71	8.83	1.19
Std. Deviation	101.65	6.91	7.73	0.50

Table 4 Descriptive statistics of news mention counts *in Two Groups of Papers*

	Papers with the highest tweet count ($N = 150$)	Papers with the lowest tweet count ($N = 150$)
Minimum	0	0
Maximum	874	15
Mean	130.78	0.55
Std. Deviation	155.65	1.79

significant, suggesting that articles from elite nations are not necessarily more important or controversial, further reinforcing the elite nations effect on tweet counts. There was also a significant positive association between tweet counts and elite institutions in medical and COVID-19 research, contrary to previous findings of insignificant relationships between tweet counts and institution and country prestige by Didegah et al. (2018). The most likely explanation is that Didegah et al. (2018) investigated multiple topics rather than focusing on health research. Thus, the patterns found here may not generalise to science-wide studies.

Scale

Highly tweeted papers tend to be more collaborative both in terms of the number of authors and countries collaborating (Table 3). The article with the largest number of authors (1242) and countries (80) was "Mortality and pulmonary complications in patients undergoing surgery with perioperative SARS-CoV-2 infection: an international cohort study" (Nepogodiev et al., 2020) conducted by the COVIDSurg Collaborative, which is an international collaborating group of surgeons and anaesthetists from more than 80 countries (CovidSurg, 2020). There was a significant Spearman correlation between tweet counts and author counts ($r_s = 0.50$, $p < 0.01$), as well as between tweet counts and country counts ($r_s = 0.31$, $p < 0.01$), although the relationship is weak for country counts. Thus, hypotheses H5a and H5b are both supported. This aligns with the previous finding by Haustein et al. (2015) that greater collaboration associates with increased Twitter attention.

News prominence

Among all 300 papers in our sample, 118 (39.3%) received no new mentions but highly tweeted articles received overwhelmingly more news coverage (Table 4). There was a

Table 5 Moderating effect of news prominence

News factors		Standardized coefficients					
Step	Predictor	β	p	R^2	R^2 *change*	F	p
Importance							
1				0.46	0.46	125.04	.000
	Importance score	0.27	.000				
	News mentions	0.53	.000				
2				0.52	0.06	106.25	.000
	Importance score	0.28	.000				
	News mentions	1.05	.000				
	(Importance score * News mentions)	−0.56	.000				
Controversy							
1				0.41	0.41	101.18	.000
	Controversy	0.13	.004				
	News mentions	0.60	.000				
2				0.43	0.02	74.17	.000
	Controversy	0.15	.001				
	News mentions	0.76	.000				
	(Controversy * News mentions)	−0.23	.000				
Elite nations							
1				0.42	0.42	107.43	.000
	Elite nations	0.18	.000				
	News mentions	0.59	.000				
2				0.44	0.02	76.86	.000
	Elite nations	0.17	.000				
	News mentions	0.80	.000				
	(Elite nations * News mentions)	−0.24	.002				
Elite persons—top medical institutions (Elite persons—M)							
1				0.41	0.41	104.85	.000
	Elite persons—M	0.16	.000				
	News mentions	0.58	.000				
2				0.45	0.04	80.34	.000
	Elite persons—M	0.19	.000				
	News mentions	0.77	.000				
	(Elite persons—M * News mentions)	−0.27	.000				
Elite persons—top institutions in coronavirus research (Elite persons—C)							
1				0.43	0.43	113.54	.000
	Elite persons—C	0.22	.000				
	News mentions	0.55	.000				
2				0.45	0.02	81.67	.000
	Elite persons—C	0.25	.000				
	News mentions	0.69	.000				
	(Elite persons—C * News mentions)	−0.21	.001				
Scale—author collaboration							
1				0.40	0.40	97.84	.000

Table 5 (continued)

News factors		Standardized coefficients					
Step	Predictor	β	p	R^2	R^2 *change*	F	p
	Scale—author	0. 09	.042				
	News mentions	0.61	.000				
2				0.44	0.04	75.82	.000
	Scale—author	0.19	.000				
	News mentions	0.83	.000				
	(Scale—author—C * News mentions)	−0.32	.000				
Scale—country collaboration							
1				0.40	0.40	99.58	.000
	Scale—country	0.11	.013				
	News mentions	0.62	.000				
2				0.41	0.01	69.83	.000
	Scale—country	0.18	.001				
	News mentions	0.75	.000				
	(Scale—country—C * News mentions)	−0.19	.011				

strong and significant Spearman correlation between news mention counts and tweet counts ($r_s = 0.82$, $p < 0.01$), supporting H6a. The strength of the relationship between news mention counts and tweet counts can also be seen in results of hierarchical regression analyses (Table 5). With standardized beta values of news mentions ranging from about 0.5–1, it had a stronger effect on logged tweet counts. Although we do not claim causality, the results are consistent with news coverage attracting tweets by drawing public attention to articles. Conversely, journalists may notice tweeted articles and write about them. This relationship is explored further below.

Moderating effect of news prominence

The hierarchical regression analyses (Table 5) indicated that news mentions moderate the relationship between tweet counts and all news factors statistically significantly at the 0.01 level, supporting hypothesis H6b. The effect was the strongest on the importance score (R^2 *change* = 0.06, $p < 0.01$). This interaction effect between news prominence and importance scores is plotted in Fig. 1. In the absence of article importance (importance score '0'), news mentions associated with increased in the (logged) tweet counts the most. For articles with an importance score of '1', the increased number of (logged) tweets was not as high. For articles with highest importance score '2', news prominence did not contribute much to (logged) tweet counts. A similar pattern can be observed with other news factors, demonstrated with Controversy in Fig. 2. This finding provides further insights into the significant positive relationship between news mentions and tweet counts reported above and in a previous study by Snehal et al. (2020). It suggests that articles with news value could attract tweets even without any press coverage.

To check the influence of news mentions on tweet counts in the absence of news value, we correlated news mentions and tweet counts for the 31 articles with no news value (i.e.,

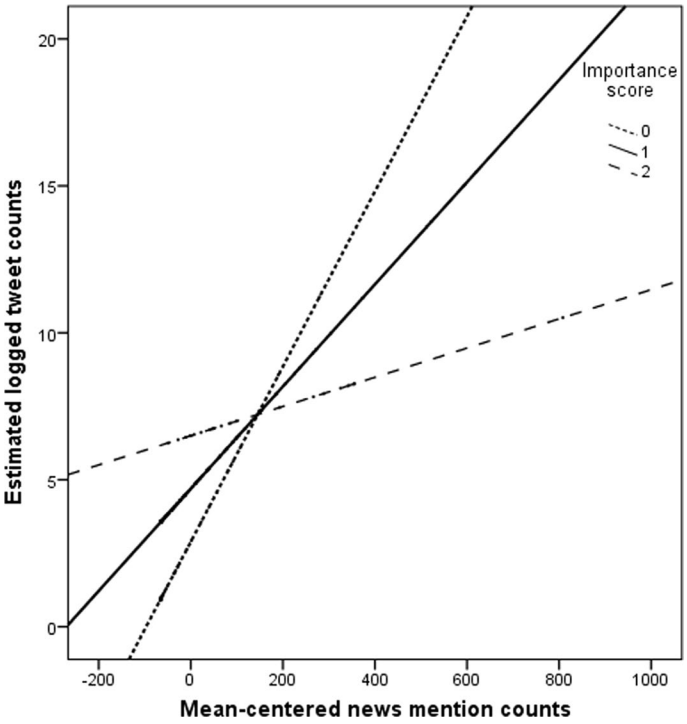

Fig. 1 Interaction effect of news mention counts and importance score on Tweet counts

no news factors). There was a slightly negative Spearman correlation between news mentions and tweet counts ($r_s = -0.22$, $p = 0.24$) although the result was not statistically significant for this small sample. A limitation of this study is that the papers were sampled based on their tweet counts. Further research is necessary to test whether news factors as general human selection criteria, rather than journalists' selections and coverage, are the primary causes of higher tweet counts. This distinction is important for the interpretation of tweet counts as research performance indicators.

Conclusion

The best way to interpret tweet counts is poorly understood, undermining their value as impact indicators. Whilst a few factors related to scholarly communication, as studied in citation analysis, have been shown to be relevant to tweet counts, this does not help to interpret their meaning. We speculated that Twitter users' decisions to share articles might be guided by their newsworthiness, as reflected by news factors, in addition to scholarly-related factors. The results suggested that the number of tweets received by 300 selected COVID-19-related research articles follows our theoretical expectations: all the news factors examined associated with higher tweet counts. Based on this finding, since these factors are hypothesised to be general human selection criteria, the results give new evidence that tweet counts are indicators of general *interest* to society, rather than scientific impact

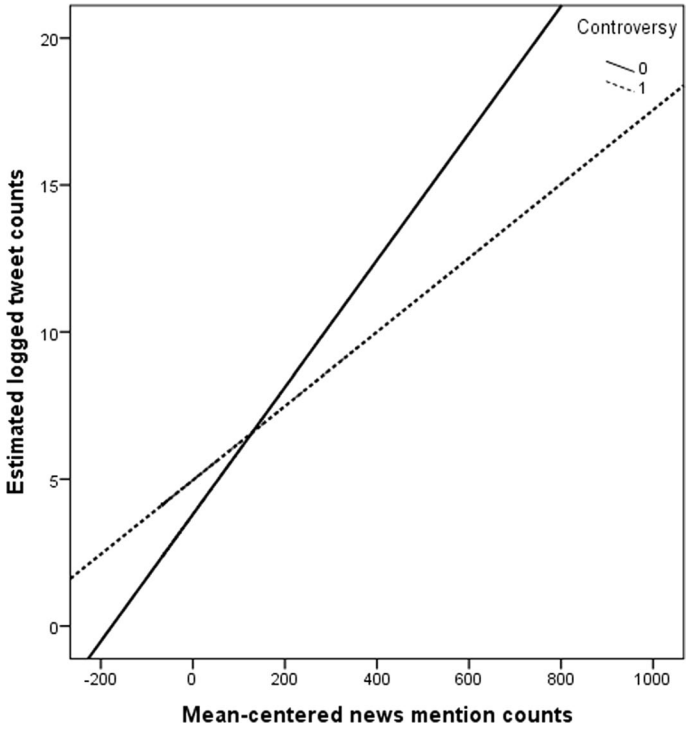

fig. 2 Interaction effect of news mention counts and controversy on Tweet counts

(as for citation counts) or societal impact (as hypothesised for altmetrics). Assuming that these tweeters are from various backgrounds, both academic and non-academic, individuals and organizations, tweet counts may be broad indicators of societal interest, at least for health research. A limitation with the evidence for this conclusion is that only COVID-19 was investigated here. Further research is required to investigate the role of news factors in different contexts.

Another major contribution of this study is that it provides a new understanding of the relationship between news mentions and tweet counts. On the surface, their strong positive relationship raises the possibility that the extent of media coverage given by journalists effects popularity on Twitter or the other way round. Nevertheless, the results of this study are also consistent with the news value of the papers attracting both tweets and news mentions.

Appendix 1

Top institutions in medicine ranked by saliency (Microsoft Academic, 2021a).

1. Harvard University
2. Johns Hopkins University
3. National institutes of health

4. Mayo clinic
5. University of California San Francisco
6. University of Washington
7. Boston Children's Hospital
8. University of Michigan
9. Stanford University
10. Brigham and Women's Hospital
11. University of Toronto
12. University of Pennsylvania
13. University of California Los Angeles
14. University of Pittsburgh
15. Duke University
16. Yale University
17. Columbia University
18. University of North Carolina at Chapel Hill
19. Emory University
20. University College London
21. Washington University in St. Louis
22. University of Oxford
23. University of Texas MD Anderson Cancer Center
24. Centers for Disease Control and Prevention
25. Northwestern University
26. University of California San Diego
27. Cleveland Clinic
28. Imperial College London
29. Memorial Sloan Kettering Cancer Center
30. University of Minnesota

Appendix 2

Top institutions in Coronavirus research ranked by saliency (Microsoft Academic, 2021a).

1. Chinese Academy of Sciences
2. University of Hong Kong
3. Centers for disease control and prevention
4. Wuhan Jinyintan Hospital
5. Huazhong University of Science and Technology
6. Peking Union Medical College
7. Chinese center for disease control and prevention
8. Wuhan University
9. Tsinghua University
10. Shanghai Jiao Tong University
11. Capital Medical University
12. Peking University
13. China-Japan Friendship Hospital
14. National Institutes of Health
15. Li Ka Shing Faculty of Medicine University of Hong Kong

16. World Health Organization
17. Erasmus University Rotterdam
18. Charité
19. Shandong University
20. University of Sydney
21. University of Washington
22. University of North Carolina at Chapel Hill
23. Harvard University
24. Fudan University
25. University of Oxford
26. University of Minnesota
27. Utrecht University
28. Pasteur Institute
29. Ludwig Maximilian University of Munich
30. University of California Los Angeles

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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