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RESEARCH ARTICLE

All the research that's fit to print: Open access and the news media

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ABSTRACT

The goal of the open access (OA) movement is to help everyone access scholarly research, not just those who can afford to. However, most studies looking at whether OA has met this goal have focused on whether other scholars are making use of OA research. Few have considered how the broader public, including the news media, uses OA research. I sought to answer whether the news media mentions OA articles more or less than paywalled articles by looking at articles published from 2010 through 2018 in journals across all four quartiles of the Journal Impact Factor using data obtained through *Altmetric.com* and *Web of Science*. Gold, green and hybrid OA articles all had a positive correlation with the number of news mentions received. News mentions for OA articles did see a dip in 2018, although they remained higher than those for paywalled articles.

1. INTRODUCTION

Advocates of open access (OA) have touted how it breaks down the financial barriers to scholarly literature by allowing anyone free access to it. This includes the general public, government officials, and the mainstream news media. The recent COVID-19 pandemic exemplifies the importance of this, as not just researchers but also medical practitioners and the general public have sought out scientific studies on the disease (UNESCO, 2020). Altmetrics now allows researchers to study this broader impact, including in the news media. However, although many studies have looked at how OA has increased the impact of scholarly work among scholars, few have studied the effect OA has had on news coverage of the scholarly literature.

The first formal definition of OA came out of the Budapest Open Access Initiative (BOAI) in 2002, which said that

By 'open access' to the literature, we mean its free availability on the public internet, permitting any users to read, download, copy, distribute, print, search, or link to the full texts of these articles, crawl them for indexing, pass them as data to software, or use them for any other lawful purpose, without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. (Chan, Cuplinskas et al., 2002, para. 3)

Although others have argued for a less stringent view of OA that does not require granting all or certain legal permissions to reuse the work, in general, most people agree that OA includes the concept of "free to read" (Bullock, 2004).

This can be seen in the number of routes to OA that have opened since the BOAI first offered its definition. These routes include what are known as

- Gold OA—Articles published in a journal that publishes all articles as OA. These journals sometimes – but not always – charge authors a fee to publish.
- Green OA—Articles and preprints that are made OA by being deposited in an open repository while still being published in a paywalled journal. Some of these articles (known as *preprints*) might have been deposited in an open repository before being submitted to a journal, whereas others were made open after they had been accepted or published, often following a publisher's embargo of anywhere from six months to several years.
- Hybrid OA—Articles published in a paywalled journal where the authors have paid a fee to make their specific article open.

Although others have offered up even more types of OA (including bronze OA and diamond OA), this article will focus on gold, green and hybrid as defined above. However, it is clear that all OA makes up a significant portion of the scholarly literature, as one study found that for articles published from 2009 to 2015, 36% were OA in some form, increasing to 45% of articles published in 2015 (Piwowar, Priem et al., 2018). There is also evidence that making research open helps to increase its impact on the academic world through increased citations (Piwowar et al., 2018). It is not clear if people outside the academic world, including the news media, have taken advantage of research being free to read. If they have not, then OA research is still not being fully utilized.

2. LITERATURE REVIEW

2.1. Importance of OA and the News Media

Dozens of studies have looked at how OA has benefited the scholarly community, often through increased citations and other measurements of a research paper's impact (McKiernan, Bourne et al., 2016; Piwowar et al., 2018). But OA can help the news media as well. Murcott (2009) argued that journalists too often rely on press releases when covering scientific research and act as translators of the research, instead of taking part in the conversation. Although Murcott called for a form of what is now known as *open peer review* to better help journalists understand the entire scholarly publishing process, making the research itself freely available can help as well. In one qualitative study, two science journalists discussed how free access to research had helped them look more critically at certain research projects, such as Andrew Wakefield's now-infamous paper on vaccines and autism, and look beyond the research published in the high-profile journals of *Nature* and *Science* (Whitehouse, 2004). One noted how OA can make his work easier, saying "The notion that there are places that we can go to browse and easily scan information, freely and at any time, is actually going to change the nature of the job quite a bit" (Whitehouse, 2004, para. 2).

In a broader sense, Noruzi (2008, para. 9) argues that OA helps to popularize science for the general public, saying "OA is at the heart of the democratization and popularization of science – helping to bring down the walls that separated science from society, knowing that both communities would benefit as a result, and enabling greater participation in scientific production."

2.2. How Science Journalists Report

A qualitative study of science journalists in Argentina, France, and Germany looked at how they decided on what to report through the Gatekeeping Theory, which Shoemaker and Vos

(2009, p. 1) define as "... the process of culling and crafting countless bits of information into the limited number of messages that reach people each day" Rosen, Guenther, and Froehlich (2016) placed the science journalists at the social institutional level. The authors found that journalists reported a variety of factors that go into their decision-making, including topics that are new, interesting, likely to generate controversy, and apply to many people. Secko, Amend, and Friday (2013) attempted to define four models of science journalism. These ranged on a continuum from translating science information for the public, providing context to science information, giving equal weight to lay information, and encouraging the public to participate in science.

Rosen et al. (2016) found that the most common sources science journalists rely on included scholarly articles, scientists, press conferences, and press releases. However, some noted that they disliked having to rely so much on press releases. This is particularly interesting in comparison to a study that found that just 49% of press releases on scholarly articles included a hyperlink to the original article and just 44% included the title of the article (Young, 2017). One science journalist noted that they do pay attention to the Journal Impact Factor (JIF), and another said they tried to stay on top of reading the scholarly literature (Rosen et al., 2016). Schäfer (2011) also found that science journalists are likely to pay attention to well-known scholarly journals, such as *Science* and *Nature*.

The amount of scholarly literature that the news media cover is minuscule, however. Suleski and Ibaraki (2010) found that in 1990, *Time* and NBC News reported on just 66 scholarly articles; more than 500,000 scholarly articles were published during that time period. They also looked at articles published in the first three months of 2001; of more than 165,000, the news outlets reported on just 55 of them. Although some studies have since found the percentage is as high as 13% (Bornmann, 2014) and 16.8% (Maggio, Ratcliff et al., 2019), others have found the news coverage of scholarly articles as low as 2% (Erdt, Nagarajan et al., 2016) and 0.5% (Costas, Zahedi, & Wouters, 2015a) of all scholarly articles.

The small percentage that the news media does report on focuses on specific disciplines. Multiple studies have found that articles focusing on health and the life sciences received the most news mentions and that astronomy and physics also tend to receive more news coverage than other scholarly fields (Bucchi & Trench, 2008; Clark & Illman, 2006; Costas, Zahedi, & Wouters, 2015b).

2.3. Using Altmetrics to Measure News Coverage

For both OA and paywalled articles, altmetrics have emerged in the past decade as a way to quantitatively measure their impact outside of traditional bibliometric measurements, such as the number of citations. First coined by Jason Priem in a tweet in 2010, altmetrics can count mentions of scholarly articles among different social media platforms, the news media, Wikipedia, and more (Konkiel, 2016). Different groups and companies have since been formed to track these measurements, including the company *Altmetric.com*, which is owned by Digital Science (Altmetric, 2015). Data connected to the measurement of altmetrics has led to a new niche in the field of bibliometrics and the impact of scholarly research.

Altmetric.com applies different weights in their formula for creating an overall score for each article and gives news media mentions the greatest weight of 8; the second highest, blog posts, receives a weight of 5 (Altmetric, 2019). *Altmetric.com* notes this is because of the assumed greater reach news mentions have than any other item that it measures, saying "It's easy to imagine that the average newspaper story is more likely to bring attention to the research output than the average tweet," (2019, para. 3). News mentions are also among

the fastest to accumulate for scholarly articles, coming behind only Reddit and Twitter for the time it took to reach 50% of all altmetric mentions (Fang & Costas, 2020). Some studies on altmetrics have focused on these types of mentions (Costas et al., 2015a; Haustein, Costas, & Larivière, 2015; Maggio et al., 2019). However, more studies have focused on using altmetrics to measure the impact of scholarly articles among social media mentions (Erdt et al., 2016; González-Valiente, Pacheco-Mendoza, & Arencibia-Jorge, 2016).

2.4. News Coverage of OA Research

A handful of studies have looked specifically at the effect OA has on whether the news media report on the scholarly literature. One study looked specifically at climate change research and found that for articles published from 2007 to 2016, OA articles were more likely than paywalled articles to receive a news mention, although paywalled articles received the most news mentions (Tai & Robinson, 2018). The study did not specify which type of OA articles it focused on. A study of works by Finnish authors also found an increase in the likelihood of receiving a news mention for OA articles but not for how many mentions an article was expected to receive (Holmberg, Hedman et al., 2019). A study of articles in the PubMed database found a correlation between OA articles and a high altmetric score, although it did not specifically look at OA and news mentions (Haneef, Ravaud et al., 2017). In a comparison of one gold OA physics journal to one paywalled physics journal, Robinson-García, Arroyo-Machado et al. (2018) found that gold OA articles received a mean of 1.22 news and blog mentions, more than paywalled (a mean of 0.23 news and blog mentions) and green OA (0.22 news and blog mentions), although it did not separate out news mentions from blog posts. A study of life sciences and biomedicine articles found both a positive correlation for the OA status of an article when looking at the likelihood of an article receiving any news mention and the number of news mentions received (Dehdarirad & Didegah, 2020).

Not all studies have always found a positive correlation, however. Fraser et al. (2019) looked at preprint articles uploaded to the open repository bioRxiv before they had been accepted to a journal and did not find an increase in the likelihood of receiving a news mention for articles that were only preprints, although they did find an increase once an article was published. The authors argued that “Preprints are also shared widely on Twitter and blogs, in contrast to mainstream media articles and Wikipedia where published journal articles still dominate, suggesting that there remains some reluctance to promote un-reviewed research to public audiences,” (Fraser et al., 2019). Another study of articles published in *Nature Communications* in 2013 and 2014, when it operated as a paywalled journal that allowed hybrid OA articles, also did not find any statistically significant difference between hybrid OA and paywalled articles for news mentions (Adie, 2014).

The prior studies have all focused on a specific niche of the scholarly literature. Only two other studies have attempted to look at the broader landscape, although on a smaller scale. Alhoori, Choudhury et al. (2015) looked at a random sample of 23 paywalled journals in the top 100 2014 *h*-index, another measurement tool similar to the JIF that considers both numbers of articles published and number of citations received. With a sample of about 27,000 articles, the authors did not find an advantage in news mentions for green and hybrid OA articles. The Open Science Monitor from the European Commission (n.d.) also included a brief look at OA and news mentions in its most recent version, finding that OA articles made up about half of all scholarly articles receiving a news mention in 2018, down from a high in 2016 when they made up 66.5%. OA articles also received a slight majority of all news mentions in 2018, also down from a high in 2016 of 69.5%.

I aim to look at a larger and more in-depth section of the research and over a broader period of 8 years to answer the following research questions:

- RQ1—How is article publication type (i.e., gold OA, green/hybrid OA, or paywalled) related to whether articles are likely to receive a news mention?
- RQ2—How is article publication type related to how many news mentions an article receives?
- RQ3—How is publication type related to other factors, such as discipline, JIF quartile, and country of news mention?

3. METHODOLOGY

I first used Journal Citation Reports (JCR) database, which includes all journals with a JIF, to determine the journals that would be used in the study sample. Scholarly journals with a JIF are often viewed as having more prestige than those that do not, although many people have critiqued using the JIF as an indicator of a journal's and article's quality (Bornmann, Marx et al., 2012; Garfield, 1999). However, I also assumed that journalists would likely be most familiar with these journals and thus most likely to report on the findings of articles published in them. Therefore, in the interest of having articles with the best likelihood of receiving a news mention, I used only journals with a JIF.

Working from disciplines identified by Suleski and Ibaraki (2010) and Atkinson, Lovett, and Baumgartner (2014) as well as other disciplines that might be covered by the news media, I focused on journals in the following JCR subjects, grouped into broader categories:

- Health—Cardiac and Cardiovascular Systems; Medicine, General and Internal; Obstetrics and Gynecology; Psychology
- Nutrition and Exercise—Nutrition and Dietetics; Sports Science
- Environment—Ecology; Environmental Sciences; Environmental Studies; Meteorology and Atmospheric Sciences
- Aerospace—Astronomy and Astrophysics
- General Science—Multidisciplinary Sciences
- Finance—Business; Business, Finance; Economics
- Social Science—Criminology and Penology; Political Science; Sociology
- Education—Education and Educational Research

For each broad discipline, I sought a representative sample of journals across the entire spectrum of the JIF. To do this, I selected the top five paywalled and top five gold OA journals (as identified by JCR) in each quartile of the broad discipline according to the JIF rankings as of June 2019. If there were not 20 gold OA journals in a discipline, all gold OA journals were included, even if there were more than five in a quartile. One paywalled journal was also in two disciplines and was counted in only one of the disciplines. This resulted in 287 journals: 159 paywalled journals and 128 gold OA journals. However, one of the most well-known and prolific paywalled journals, *Proceedings of the National Academy of the Sciences (PNAS)*, was removed because in 2017 it switched to being a bronze OA journal, meaning that it makes all of its articles free to read after a certain period (in this case, six months). It also made all prior articles included in this study sample OA, even if initially they were paywalled, meaning it was impossible to separate paywalled articles from green/hybrid OA articles, which in turn could muddy the results. This resulted in 158 paywalled journals in the study (Table 1).

Table 1. Breakdown of journals by subject category, including number of paywalled journals, number of OA journals, median number of articles by subject, and median JIF by subject

Subject	Paywalled journals	OA journals	Median articles	Median JIF
Astrophysics	20	7	686	2.333
Business/Economics	20	19	247	1
Education	20	12	279	1.4755
Environment	20	20	521.5	2.331
General Science	19	19	730.5	1.7615
Health	20	20	666.5	2.9195
Nutrition/Exercise	19	20	697	2.591
Social Sciences	20	11	272	1.5405

In June 2019, the ISSNs of the journals were then searched in *Altmetric.com*'s Explorer dashboard, which provides researchers access to *Altmetric.com*'s data, for any articles published in those journals from 2010 through 2018 and that received a news mention from 2010 through May 2019. *Altmetric.com* curates a large list of news sites (about 2,400 as of spring 2020) that it searches for news mentions to scholarly articles (*Altmetric*, 2016). For paywalled journals, a second search was performed using a filter for only articles that *Altmetric.com* had identified as having a green or hybrid OA version available. Because *Altmetric.com* did not distinguish whether an article was green or hybrid, I categorize them together as green/hybrid. I did not search to see if articles published in gold OA journals also had a green OA version available, and therefore all articles from these journals are categorized as being gold OA.

I then exported the metadata for these articles as a CSV file, which included a record for each time a news article had mentioned a scholarly article, meaning that some scholarly articles had multiple records. The metadata also included the year of the news mention as well as the country where the news mention originated from, both determined by *Altmetric.com*.

In October and November 2019, I used the Web of Science database to export the metadata for all items identified as Articles, Editorial Material, Letters, Reviews, and Proceeding Papers published in the same scholarly journals from 2010 through 2018. I opted to focus on these item types as the most likely ones to receive a news mention. The metadata for the articles included the JIF score for their associated journal.

I used RStudio, an open source program for statistical computing, to clean and identify the final three main groups of data:

- all articles from gold OA journals,
- the subset of all green/hybrid OA articles from paywalled journals, and
- the subset of all fully paywalled articles from paywalled journals.

For articles from both *Altmetric.com* and Web of Science, this included deduplicating the subset of green/hybrid OA articles from all articles published in paywalled journals to create another subset of articles from paywalled journals that were entirely paywalled. Any articles that did not have a Digital Object Identifier (DOI), which is a unique identifier for each article,

Table 2. Number of articles deleted by data set because they were missing a DOI

Data group	No. of articles deleted
Altmetric.com gold OA articles	62
Altmetric.com green/hybrid articles	378
Altmetric.com paywalled articles	818
Web of Science gold OA articles	12,841
Web of Science green/hybrid articles	1,114
Web of Science paywalled articles	16,899

were deleted as it would not be possible to match them with the corresponding article among the Web of Science data sets and the Altmetric.com data sets (Table 2).

Any articles that did not have a matching article among the Altmetric.com or Web of Science articles were deleted, which resulted in 6,907 paywalled articles, 2,077 green/hybrid OA articles, and 608 gold OA articles being deleted. I deduplicated the Altmetric.com articles from the Web of Science articles to determine which articles had not received any news mention. Seven journals had no articles that met all of the above criteria. For unique articles in the study sample, $N = 590,915$.

Both RStudio and Stata were used to analyze the data. The Poisson and negative binomial models are normally used to analyze count data. However, Poisson assumes that the variance is equal to the mean. In this case, the mean of all news mentions is 1.47, whereas the variance is 795. In cases where the variance is greater than the mean, negative binomial is more appropriate. At the same time, a large number of zeros in the count data suggests using a zero-inflated negative binomial. This is a two-part model, with the first part looking at the number of counts and the second logit part looking at excess zeros. Because of the high number of articles with no news mention in this sample (86.9%), the author opted to use the zero-inflation negative binomial test to analyze the results. The Akaike information criterion (AIC), a goodness of fit model, confirmed using the zero-inflated negative binomial model over the zero-inflated Poisson model. Further, I again relied on the AIC to determine which variables to include in the model by running different combinations of variables, ultimately settling on the access status of an article, the JIF, and the article publication year as the independent variables for both parts of the model.

3.1. Limitations

Altmetric.com uses two methods to search news sites for mentions of scholarly articles: automatically searching for hyperlinks to scholarly articles and searching in English for mentions of scholarly articles. The site also works to include content in languages other than just English. Despite this effort, however, there is no guarantee that Altmetric.com searches all news sites, and thus this research project likely underestimates these mentions. It is also likely that the company gives preference to English language publications, limiting the news mentions from non-English language outlets. It is also not clear when Altmetric.com added all the news sites, which could affect the number of news mentions for all articles over time.

The project also relied on identifying articles through the DOI and had to delete articles that did not have a DOI, whether in the Altmetric.com or Web of Science data set, which also means this study is missing articles that both did and did not receive news mentions.

I was not able to determine if all articles in the green/hybrid OA category were actually open at the time of a news mention. This is particularly problematic for green OA articles, as some journals do require authors to wait for a certain period before making the article open, meaning that no open version might have been available when some of the news mentions were published. It is also unclear whether journalists are aware of the various routes to find green OA articles. Although several studies have shown Google Scholar and tools such as Unpaywall and Open Access Button make this relatively easy and effective, journalists would still need to first be aware of these discovery options (Martín-Martín, Costas et al., 2018; Schultz, Azadbakht et al., 2019). Finally, some research is starting to show that more privileged scholarly authors—White men in senior positions at research institutions with known prestige and the resources to pay expensive publishing fees—are most likely to pay to publish OA, which almost always includes hybrid OA (Olejniczak & Wilson, 2020). The factors that make it more likely for privileged authors to publish hybrid OA could also play a role in whether those articles receive a news mention.

As discussed later, although the study included fewer gold OA journals in the overall sample, gold OA articles made up a majority of all articles, mostly thanks to large megajournals, such as *PLOS One* and *Scientific Reports*. The large number of articles from a small number of journals could potentially skew the results.

Finally, it should be stressed that many factors can go into whether the news media writes about a scholarly article (including whether a scholarly journal has issued a press release), some of which cannot be easily measured and that were not included in this study.

4. RESULTS

Although there were not as many gold OA journals in the study as paywalled journals, gold OA articles made up almost two-thirds of the study sample at 63% (Table 3). A large part of this appears to be because of the number of articles published by the megajournal *PLOS One* – 193,931. *Scientific Reports*, another gold OA megajournal, came in second with 80,654 articles total. Paywalled articles made up the second largest section of the study sample with 26%, and green/hybrid OA articles made up the smallest portion at 11%.

Overall, 13% (77,255) of all articles received at least one news mention. Just 11% of gold OA articles and paywalled articles received a news mention, whereas 47% of green/hybrid OA articles did.

In looking at just those articles that received a news mention, the median number of news mentions for all articles was three, which was also the same for gold OA and paywalled

Table 3. The number and percentage of gold, paywalled, and green/hybrid OA articles overall in the study and that received at least one news mention

Article type	Total articles	% of all articles	Articles with a news mention	% of all articles with a news mention
Paywalled	159,514	27	17,663	22.9
Gold	393,610	66.6	41,586	53.8
Green/hybrid	37,791	6.4	18,006	23.3
All	590,915	100	77,255	100

Table 4. Results of the count portion of the zero-inflated negative binomial model. For all values, $p < .001$

Variable	Coefficient	Z	Exp (coefficient)	95% confidence interval
Gold OA	0.52	25.95	1.7	0.49, 0.57
Green/hybrid OA	1.21	65.28	3.34	1.17, 1.24
JIF	0.02	36.09	1.02	0.015, 0.017
Article publication year	0.28	96.18	1.32	0.27, 0.28
Intercept	-560.57	-96.17	0	-571.99, -549.14

articles. Green/hybrid articles received a median of five news mentions. There were 1,372,799 individual news mentions.

The zero-inflated negative binomial model found that both gold and green/hybrid OA articles were positively associated with an increase in the number of news mentions (Table 4). It also found that both were negatively associated with excess zeros (or the probability that an article received no news mentions) for news mentions; in other words, gold and green/hybrid OA articles would be positively associated with receiving any news mentions (Table 5). Although *PNAS* was not included in these results, a separate analysis that did include it found that the results for median numbers of news citations for all article types remained the same, as well as the positive correlations for all OA article types. Because of the potential for articles from *PLOS One*, which made up a large portion of all gold OA articles in the study sample, to skew results, another analysis was also performed that subtracted out both *PNAS* and *PLOS One* articles. The results changed little from those in Tables 4 and 5, and thus the study continued to include *PLOS One* articles.

4.1. Top Journals

A large majority of articles receiving a news mention (80%) were published in 10 journals, five of which are gold OA journals (Table 6). All of the journals except for one – *PLOS One* – were ranked in the top quartile of their discipline in Journal Citation Reports for 2018. *PLOS One* was ranked in the second quartile, although it had been in the first quartile from 2012–2017. Of the top 10 journals with the most OA articles that received a news mention, six were gold OA. Among the four that were paywalled, OA articles made up more than half of the articles that received a news mention for three journals (Table 7).

All but two of the top 10 journals were also categorized in the general science subject category, which includes journals that are considered to be megajournals, which tend to publish

Table 5. Results of the excess zeros portion of the zero-inflated negative binomial model. For all values, $p < .001$

Variable	Coefficient	Z	Exp (coefficient)	95% confidence interval
Gold OA	-0.93	-40.58	0.39	-0.98, -0.89
Green/hybrid OA	-1.69	-46	0.18	-1.77, -1.62
JIF	-0.37	-90.79	0.69	-0.37, -0.36
Article publication year	0.03	8.06	1.03	0.02, 0.03
Intercept	-50.51	-7.55	0	-63.62, -37.39

Table 6. The 10 journals with the most articles regardless if OA or paywalled receiving a news mention and how many total articles each journal had in the study sample. * = gold OA journal

Journal	No. of articles with at least one news mention	% of all articles receiving a news mention	No. of total articles	% of articles from journal receiving news mention
<i>PLOS One</i> *	14,514	16.5	193,931	7
<i>Nature Communications</i> *	9,035	10.3	21,970	41
<i>Nature</i>	8,549	9.7	16,781	51
<i>Scientific Reports</i> *	8,467	9.6	80,654	11
<i>Science</i>	7,371	8.4	14,118	52
<i>New England Journal of Medicine</i>	4,450	5	8,546	52
<i>JAMA</i>	3,340	3.8	9,138	37
<i>The Lancet</i>	3,282	3.7	12,458	26
<i>Science Advances</i> *	1,619	1.8	2,421	67
<i>Environmental Research Letters</i> *	1,045	1.2	2,939	36

the most articles in a large swath of disciplines. Articles from this category made up 66.8% of all articles that received a news mention, followed by health (18.2%) and environment (6.2%) (Table 8). No other subject made up more than 5% of news mentions overall.

Gold OA articles received more than half of the news mentions from the general science journals, although this was less than their share for the subject area when looking at all

Table 7. The top 10 journals with the most OA articles that received at least one news mention, compared to how many articles from that journal overall received at least one news mention. * = gold OA journal

Journal	No. of OA articles with at least one news mention	% of all articles from journal receiving a news mention
<i>PLOS One</i> *	14,514	100
<i>Nature Communications</i> *	9,035	100
<i>Scientific Reports</i> *	8,467	100
<i>Nature</i>	5,529	64.7
<i>Science</i>	3,653	49.6
<i>JAMA</i>	1,939	58.1
<i>New England Journal of Medicine</i>	1,906	42.8
<i>Science Advances</i> *	1,619	100
<i>Environmental Research Letters</i> *	1,045	100
<i>PLOS Medicine</i> *	980	100

Table 8. Breakdown of articles by subject, including the percentage each subject makes among all articles and the percentage of each subject among articles that received a news mention

Subject	% of all articles	% of articles receiving a news mention
General Science	62	67
Health	12	18
Environment	9	6
Nutrition/Exercise	7	5
Astrophysics	6	2
Social Sciences	2	1
Business/Economics	2	1
Education	2	0.5

articles (Figures 1 and 2). Meanwhile, green/hybrid OA articles also received a majority of the news mentions among the articles from astrophysics journals and actually saw their share increase in all the disciplines for articles that received a news mention when compared to their share among the disciplines for all articles regardless of whether they received a news mention. Paywalled articles dominated among news mentions from the social sciences, business/economics, and education, although their share among all articles with a news mention was smaller compared with their share among all articles in all disciplines but general science. It should also be noted that education had only 12 gold OA journals and social sciences had only 11, none of which were in the first or second quartile, which also likely affected the share of gold OA news mentions in those areas. Most of the gold OA social science journals are also non-English language journals, which could also affect the chance that they would receive a news mention in the outlets tracked by *Altmetric.com*.

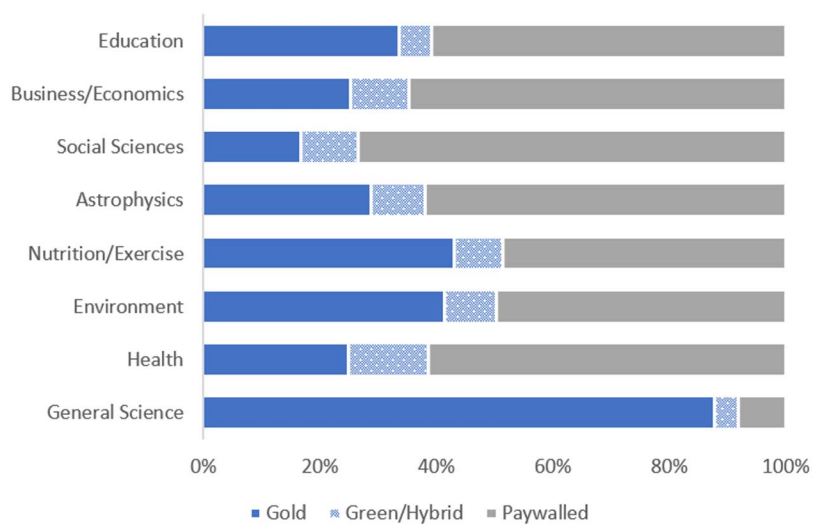


Figure 1. The share of all gold OA, green/hybrid OA, and paywalled articles, regardless of news mention, by subject.

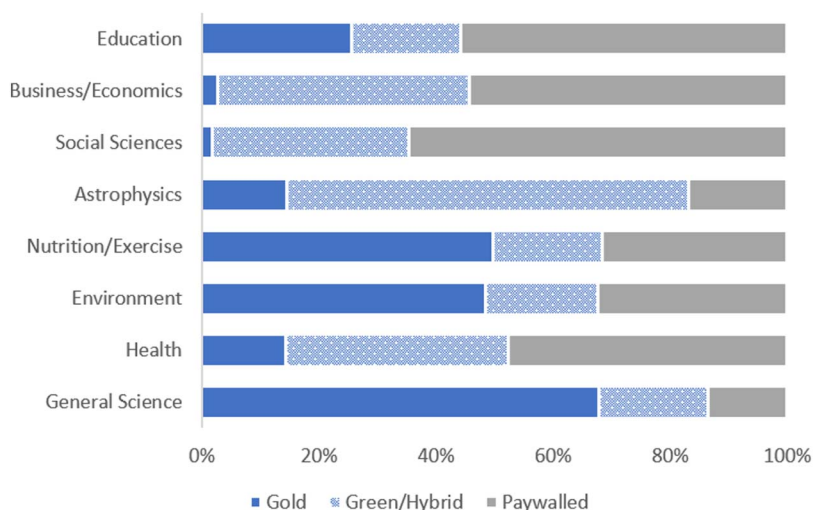


Figure 2. The share of gold OA, green/hybrid OA, and paywalled articles that received a news mention by subject.

4.2. JIF Quartiles

Articles from journals in the first JIF quartile made up a large majority of the study sample (71.9%), and second, third, and fourth quartile articles made up 13.9%, 9.1%, and 5.1%, respectively, of the overall sample. The majority for first quartile articles increased to 91% of articles receiving a news mention. OA articles made up almost 80% of articles in the first quartile that received a news mention; however, their share dropped for each quarter (Table 9).

4.3. Country of News Mention

A large minority of the records for the individual news mentions (39.5%) did not include what country the news mention was published in. Broken down by type, 50.8% of gold OA articles, 45.3% of paywalled articles, and 6.7% of green/hybrid OA articles were missing the country of news mention. Of those that did include country of news mention, the United States received the largest portion, with 34.7%. The United Kingdom, which was second, had just 8.6%, and Australia was third with 3%. Gold OA articles saw the widest difference in the percentage of news mentions they made up by countries, with a difference of 17 percentage points (Figure 3). India (55%) saw the highest percentage of news mentions dedicated to gold

Table 9. Percentage of all gold OA and green/hybrid articles in each quartile and the percentage of gold OA and green OA articles among articles that received a news mention in each quartile.

Quartile	% gold OA in quartile	% gold OA in quartile articles with mention	% green/hybrid in quartile	% green/hybrid OA in quartile articles with mention
First	79	56	6	23
Second	33	40	10	30
Third	34	23	7	36
Fourth	39	26	6	20

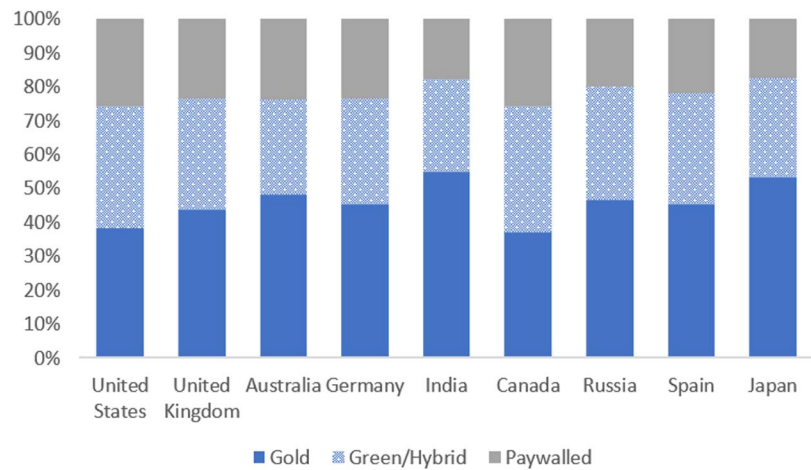


Figure 3. The percentage that gold OA, green/hybrid OA, and paywalled articles each made up among news mentions in the 10 countries with the most news mentions overall.

OA articles, and Canada (37%) registered the highest percentage for green/hybrid OA articles, as well as the highest portion of paywalled articles (26%).

4.4. Year of News Mention

The same news mentions that did not include a country also did not include a year of publication of the news mention. Another 247 news mentions appear to have the incorrect publication year, as the year listed is prior to 2010. For those that did have a publication year matching the criteria, mentions saw steep growth up until 2016 and then a decrease through 2018 (Figure 4). Although 2019 was not included in Figure 3 as it only included news mentions through May, it is interesting to note that there were just 26,143 total news mentions through the first 5 months of the year, just 15% of 2018's total. It is unclear, however, if changes to Altmetric.com's data collection account for this decrease or if it is related to the subset of articles missing the publication year.

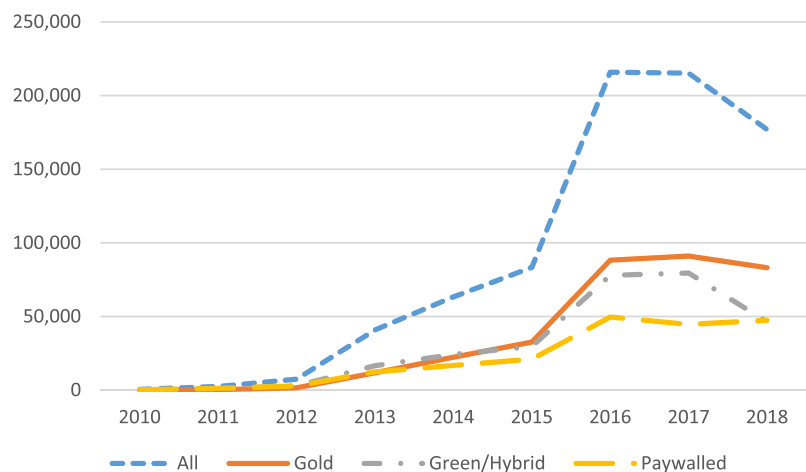


Figure 4. News mentions of scholarly articles published per year and by article type.

5. DISCUSSION

Overall, the percentage of all scholarly articles that received a news mention (13%) matched the higher rates found by prior studies looking at how much the news media writes about the scholarly literature (Bornmann et al., 2012; Maggio et al., 2019). This is likely because of this study's focus on high-impact journals that many also perceive as having the highest reputations, which could mean journalists are most likely to pay attention to and write about their published findings.

The findings of this study also appear to agree with those of smaller projects that found a connection between OA and news mentions and suggests that the OA status of an article could play a role by providing easier access to the source material for science journalists. Although the study showed a positive association for all OA articles and an increase in news mentions, the bump for green/hybrid seems particularly of interest. This is especially true when comparing the findings to those by Fraser et al. (2019) that preprint articles, which are part of green OA, on their own did not receive a boost in news mentions but did after the article was published. The higher rates of news mentions for green OA articles in this study could also then be related to green OA articles that had been published and thus science journalists saw them as having more quality and credibility. Another explanation could be that the advantage actually lies with hybrid articles, although Adie (2014) also did not find a statistical advantage for hybrid OA articles. Without being able to separate green and hybrid OA, it is impossible to say if one or the other exerted greater influence.

One other factor could be time, both in the form of the news media's growing awareness of OA and scholarly publishers' own willingness to support various versions of OA. All OA articles saw a steady growth in news mentions from 2012 to 2016 that outpaced those of paywalled articles, and in fact gold OA article news mentions outpaced green/hybrid articles starting in 2016. At the same time, although all OA articles saw a decrease in news mentions in 2018, paywalled articles saw a slight increase, although not enough to overtake OA articles. The overall decrease could be due to any number of factors not related to the access status of an article, such as changes to the news sites that [Altmetric.com](https://www.altmetric.com) uses for this variable.

Because journal reputation and familiarity likely do not play as much of a role among journals in the lower quartiles, it would make some sense for the benefit of ease of access to OA articles in these quartiles to lead to a greater proportion of articles receiving a news mention. To an extent, this was true, with green/hybrid OA articles seeing a substantial increase in their share of articles receiving a news mention across all quartiles. Gold OA articles, however, only saw their share increase in Q2, but their share dropped slightly in Q3 and Q4. However, their share did not drop as much as paywalled articles did in Q3, and paywalled articles also saw their share drop in Q4. This suggests that a mix of factors, including OA status and journal reputation, could be involved in whether articles receive a news mention, even among journals in the lower quartiles.

As a gold OA journal, *PLOS One's* place atop the journals with the most news mentions is promising; it had a third more than the second-place journal. However, the large number of articles published by the journal means that the percentage of its articles that receive a news mention is much smaller than the other journals in the top 10. The number of articles that *PLOS One* publishes each year has been dropping (Straumsheim, 2017), so it would be worthwhile to continue to measure changes to its percentage of articles receiving a news mention. The fact that all the journals in the top 10 have well-established reputations or come from publishers with a well-established reputation suggests that familiarity still plays a strong role in what scholarly literature the news media covers. The ability of large publishers to put

resources into marketing the articles they publish, such as by issuing press releases and having public relations departments to work with the news media, could also be at play.

Considering the large share that gold OA megajournals have overall in news mentions, it is not surprising that the general sciences also dominated news mentions among the other disciplines. The strong preprint culture in physics and astronomy through the repository arXiv also likely led to that discipline having the highest share of green OA articles with a news mention. Likewise, the weaker culture of all OA in the social sciences and education likely played a role in paywalled articles seeing more news mentions for those fields. This is likely affected by the lack of gold OA journals in the Q1 or Q2 for social sciences, but this also emphasizes how gold OA does not play a strong role in this disciplinary area. However, paywalled articles also dominated in business and economics, despite the fact that economics also has a long-established preprint culture with the RePEc repository.

In terms of countries where the news mentions were published, no one country dominated in any of the access categories. Although India (55%) certainly saw the highest rate of its news mentions refer to gold OA articles, the United States still had more than a third of its news mentions come from gold OA articles. The same was true for green/hybrid OA articles, where India actually had the smallest proportion at 36%. This seems to hint that there is no geographical basis for a bias for or against OA scholarly articles, although more evidence is needed.

6. CONCLUSION

The inherent purpose of OA is to ensure access for everyone to the scholarly literature. Dozens of studies show that this is true for the scholarly community, but relatively little research has looked at whether that has translated into the general public seeing the same benefit. The news media play a large role in what the general public sees and understands about the scholarly literature, so it is important that journalists take advantage of open scholarship. This study provides some evidence that the news media are exercising this to an extent, but more could be done to help educate journalists about OA, including how to evaluate all scholarly articles and how to find OA versions. Also, as some scholars have expressed concern about the general public's ability to understand the difference between scholarship that has and has not been peer reviewed (Heimstädt, 2020), especially during the COVID-19 pandemic and the rush to get research findings out through preprints, it is important for journalists to understand how preprints work and to convey this difference to their readers.

This study adds to the growing body of literature investigating just how much the news media report on OA scholarly articles. The evidence shows a positive correlation for gold, green, and hybrid OA over paywalled articles. However, more research is needed to help determine how much of this is because of a causation effect, if any, as well as how other factors such as press releases, author characteristics, and other issues affect this relationship. Further research could also ascertain the difference between how the news media report on green and hybrid articles, as well as how science journalists view OA, including if they report on OA literature because it is OA or if they even realize it is OA.

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DATA AVAILABILITY

Because of limitations with the access agreement with Altmetric.com, the author is unable to share the base data underlying the study.

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