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GOING FOR GOLD: EXPLORING THE REACH AND IMPACT OF GOLD OPEN ACCESS ARTICLES IN HYBRID JOURNALS
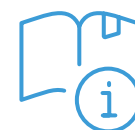
White paper

Open Research: Journals, books, data and tools from:

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Contents

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Foreword

Publishers, institutions and researchers have been working together for many years to make the transition to open access (OA) a reality. At Springer Nature, we see full (Gold) OA, where the outputs of research are immediately available to all, as the best, most complete and most sustainable route to achieve this. It is why, over the past twenty years, we have put transitioning to full OA for all of the primary research we publish at the heart of our business. From our BMC imprint, the first commercial OA publisher, and our pioneering Springer Compact agreements which paved the way for today's Transformative Agreements (TAs), to introducing the concept of Transformative Journals (TJs) and providing all authors with the ability to publish OA in *Nature* and our other highly selective titles, we are committed to making the final version of record (VOR) of all primary research open to all.

Over this time we have also been committed to helping publishers, authors, funders and others better understand the drivers and benefits of OA publishing by gathering data and sharing research.

Assessing the open access effect for hybrid journals compared OA articles published in hybrid journals with non-OA articles published in the same journals. It found that the OA articles had higher citations, were downloaded more, and achieved greater impact via Altmetrics scoring than non-OA articles.

Further white papers followed, including *Open for all: exploring the reach of open access content to non-academic audiences*, and earlier in 2021 *Exploring researcher preference for the version of record*. This last one provided an important addition to our bibliometric analyses as it explored which version of the article researchers actually prefer to use, finding that it is the final published VOR that is preferred by researchers for their reading and research as it can be relied on, is accurate, and is up to date.

Together, these all point to a very clear conclusion: having the final VOR immediately available from the moment of publication to be discovered, shared, used and reused, benefits authors, researchers, and, because it acts as an integrated hub for all of the elements necessary for open science including data and code, benefits science itself.

I am therefore delighted that with this latest white paper, *Going for gold: exploring the reach and impact of Gold open access articles in hybrid journals*, we are able to provide an additional and updated contribution to the existing body of research.

It confirms the 'OA effect' which sees OA articles in hybrid journals achieving greater impact, usage and reach than comparative non-OA articles. However, by looking especially at subscription articles where an earlier version (such as a

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Green OA accepted manuscript) exists in an OA repository, it also shows that there is no significant corresponding 'Green OA effect'. The existence of a 'Green' version is not sufficient to match the benefits of Gold OA if the VOR it is attached to is behind a paywall.

This matters because we are currently at a crossroads with the belief that Green OA is a suitable substitute for Gold OA filtering through in funder policies and mandates. This is not only a false choice as explained above; policies, such as the Rights Retention Strategy from Plan S, that seek to place Green OA on a par with Gold OA, are misleading authors. Not only is Green OA not a sustainable option for a transition to fully OA, with its continued reliance on library subscription payments, it is less desirable to researchers, offering less utility and reliability. And now we can also see that the existence of a Green version just doesn't deliver the advantages in terms of reach and impact of research outputs that an article achieves when published Gold OA. It's critical that we continue to invest in a Gold OA future, and continue to invest in enabling authors to select Gold OA in the journals of their choice.

Executive summary

In 2021, Springer Nature commissioned an analysis of 60,567 articles published in 1,262 of its hybrid journals, measuring reach by the number of downloads and the attention reflected in the Altmetric Attention Score, and impact through the number of citations.

This white paper presents the findings from that analysis, which show a clear advantage in reach and impact for articles published OA in hybrid journals compared to non-OA articles in the same journals, and for the first time also an advantage for full (Gold) OA articles compared to subscription articles where an earlier article version (such as an accepted manuscript (AM) or preprint) has been self-archived in an OA repository.

This study compares downloads, citations and attention of articles published in hybrid journals with the following article classifications:

Gold OA VOR (summarised as **Gold OA** in all tables): Immediate access on publication to the final published VOR for all.

Subscription VOR with earlier version available in a repository (summarised as **EarlyV** in all tables): A self-archived copy of an earlier article version, such as the AM or preprint, is available in a publicly accessible institutional or subject repository.

Subscription VOR without earlier version available (summarised as **Non-OA** in all tables): All other subscription articles, including those shared only on an academic social network or illegally elsewhere.

> Gold OA articles in hybrid journals on average achieve greater reach and impact, compared to subscription articles with earlier versions available, and to non-OA articles

Key findings

For Springer Nature authors who have selected the full Gold OA publishing option, there is clear evidence that their work has benefitted from increased attention and reach.

Articles published via the Gold OA route in hybrid journals on average achieve greater reach and impact, compared to subscription articles with earlier versions available, and to non-OA articles.
- Gold OA has the greatest citation advantage. This is 1.64 times higher than non-OA, or 2.12 times higher in the predictive model[1]
- Gold OA also has a higher citation advantage compared to subscription articles with earlier versions available, which only achieve 1.07 times higher citations than non-OA, or 1.17 times higher in the model)

1. Predictive models were built to estimate the reach and impact that could be expected when taking into consideration some of these wider factors at the document, author, and journal level. See Methodology for more information.

- Gold OA achieves greater reach. This is 6.02 times more downloads than non-OA on average (6.52 times as many downloads predicted in the model)
- Gold OA achieves increased attention. On average, Gold OA articles have 4.91 times as high an Altmetric Attention Score (Altmetric score) as non-OA articles, while subscription articles with earlier versions available have 2.10 times as high an Altmetric score as non-OA articles in hybrid journals, on average.

Variations by discipline are seen but Gold OA exceeds the reach and impact of both non-OA articles and subscription articles with earlier versions available.

- Although there is wide variation by subject area, there is a clear advantage for OA compared to non-OA across every discipline
- Gold OA articles outperformed both non-OA articles and subscription articles with earlier versions available on all three measures in nearly every discipline, looking both at averages and predicted models (in the case of Materials Science, only for the predicted average)
- Overall, there is a citation advantage for Gold OA with up to 2.32 times as many citations compared to non-OA, (up to 3.61 times as many in the model) - with the exception of Materials Science, only for the predicted average. The citation advantage for Gold OA continues when compared to subscription articles with earlier versions available, with up to 1.38 to 1.89 times as many citations as non-OA (Table 5)
- For downloads, Gold OA articles always achieved more downloads across all subjects than either non-OA or subscription articles with earlier versions available, ranging from 3.79 times as many in Mathematics to 6.13 times as many in Life Sciences (Table 6)
- Typically, there is a far larger Gold OA Altmetric score advantage ranging from 3.57 to 6.60 times as many, compared to 1.73 to 4.19 times as many for subscription articles with earlier versions available (Table 7)
- The largest Altmetric score advantage seen is for Gold OA articles in Mathematics with 6.60 times as many on average, or based on the predictive model, the Life Sciences has the largest advantage with 7.30 times as many. The lowest Altmetric score advantage comes from subscription articles with earlier versions available in the Life Sciences, with 1.73 times as many on average (or based on the predictive model, 2.17 times as many).

Conclusions

Our findings show not only that Gold OA articles attract more citations, more downloads, and higher Altmetric scores on average, compared with non-OA articles, but for the first time we have clear evidence of an advantage for Gold OA compared to subscription articles where earlier versions are available.

The results support our previous examinations of the benefits of OA for authors, compared to non-OA, but importantly also show the particular

benefits of full Gold OA in enabling immediate access to the VOR, compared with subscription-tied sharing of early versions, such as the AM via Green OA. In a previous white paper we showcased researcher preference for the final VOR, both for reading but in particular for citing content in their own work—83% preferred the final VOR compared with just 9% preferring AMs.[2] Together, these reports demonstrate that the increased availability of the VOR via Gold OA offers significant benefit to the research community.

We believe that this white paper presents a robust case for continued funding and investment from funders for full Gold OA articles in hybrid journals. For Springer Nature authors who have selected the Gold OA publishing option, there is clear evidence that their work has benefitted from increased attention and reach.

The introduction of policies which restrict funding for OA publishing in hybrid and TJs is counterproductive. Enabling funding of OA publications via TAs is helpful, but since many authors and organisations are not yet covered by TAs, this route is, by itself, insufficient and needs to be supported with other transitionary funding measures. Efforts which seek to increase the availability of Green OA don't create the intended benefits and risk delaying or even preventing the take up of full Gold OA and achieving the benefits described above. While sharing of subscription-tied earlier versions can help the dissemination of research, they do not have as strong a reach or impact as full Gold OA, and remain dependent on the continuation of subscription models to fund the costs of editorial and publishing processes to validate and improve the manuscript. As such, we believe investment in Gold OA should be a priority and is the only way to achieve full, immediate and sustainable OA.

We believe investment in Gold OA should be a priority and is the only way to achieve full, immediate and sustainable OA

2. Lucraft, M. *et al.* (2021). *Exploring researcher preference for the version of record* [White paper]. Springer Nature. https://figshare.com/articles/dataset/_/13834532

Introduction

Worldwide, there continues to be an increasing number of OA policies and mandates, as well as updates to existing policy requirements.[3] At the time of writing, there have been significant policy developments in 2021, including the policy introduced by Plan S in January 2021 for researchers who have been funded by certain members of cOAlition S,[4] and in August 2021 UKRI's policy was announced for UKRI-funded articles from April 2022 and books from 2024.[5]

Certain members of cOAlition S have chosen not to fund APCs for TJs, which has the effect of excluding many authors from selecting OA in hybrid journals by restricting funding only to those journals and authors covered by TAs.

In addition, some policies seek to increase the availability of the AM, via Green OA. Publishers including Springer Nature have set out arguments in favour of investment in full Gold OA however, determining that a focus on subscription-tied Green OA through sharing of the AM risks undermining progress to full OA.[6,7] These policies seem to conflict with the potential benefits to authors of publishing Gold OA in hybrid journals, where immediate access is given to the Gold standard VOR, preferred by researchers for both reading and citing.[8]

This white paper explores the impact and reach of different types of articles in hybrid journals—journals that contain both a mixture of OA and non-OA articles. The work builds on two of Springer Nature's earlier white papers exploring the reach and impact of OA articles: *Assessing the open access effect for hybrid journals*,[9] and *Open for all*.[10] The first white paper explored the reach and impact advantage of OA articles within Springer Nature hybrid journals compared to non-OA articles, and found that there were significant advantages both globally and in the UK for those published OA.

The second white paper, *Open for all*, looked more broadly at the reach and impact of different types of journals. It not only found that the downloads of Gold OA content published under a hybrid OA model were significantly higher than for downloads in fully OA publications, but also that there were additional advantages in the predicted amount of Altmetric attention and citations. This advantage is typically ascribed to hybrid journals being longer established and more prestigious than many of the newer fully Gold OA publications.

With this report, we return to the study of hybrid journals, exploring for the first time whether Gold OA articles achieve greater reach and impact compared both to subscription articles with only access to paying subscribers, and also to subscription articles where an earlier version (such as an AM) is available in a publicly accessible repository. The analysis is based on 60,567 articles, which were published in 1,262 different Springer Nature hybrid journals in 2018. The strength of Springer Nature's portfolio allows this topic to be examined in depth with both a large sample size and range of disciplines providing a robust and unique study. Utilising our previous research methodology, we explore reach by the number of downloads and the attention reflected in the Altmetric score, and impact through the number of citations.

In Part 1, we focus on citations, downloads and Altmetric scores across all disciplines. In Part 2 and Appendix 2, we also include a deep dive into a selection of core research disciplines.

3. ROARMAP (n.d.). Retrieved October 7, 2021 from http://roarmap.eprints.org/

4. *About Plan S* (n.d.). Retrieved October 7, 2021 from https://www.coalition-s.org/

5. *Shaping our open access policy* (n.d.). UK Research and Innovation. Retrieved October 7, 2021 from https://www.ukri.org/our-work/supporting-healthy-research-and-innovation-culture/open-research/open-access-policies-review/

6. Webster, C. (2021). *UKRI's new open access policy will hinder open science*. Times Higher Education. Retrieved October 7, 2021 from https://www.timeshighereducation.com/blog/ukris-new-open-access-policy-will-hinder-open-science

7. *Open post: The rise of immediate green OA undermines progress* (2020). OASPA. Retrieved October 7, 2021 from https://oaspa.org/open-post-the-rise-of-immediate-green-oa-undermines-progress/

8. Lucraft, M. *et al*. (2021)

9. Draux, H. *et al*. (2018). *Assessing the open access effect for hybrid journals* [White paper]. Springer Nature. Retrieved October 7, 2021 from https://www.springernature.com/gp/open-research/about/oa-effect-hybrid

10. Wirsching, H. *et al*. (2020). *Open for all: exploring the reach of open access content to non-academic audiences* [White paper]. Springer Nature. https://zenodo.org/record/4143313#.YWYBoNrMKUn

Methodology

60,567 articles published in 2018 in 1,262 Springer Nature hybrid journals (whose imprints include Springer, Palgrave Macmillan and Nature.com's Academic Journals[11]) were included in this study.

The difference in impact and reach for the different publishing models was analysed using the statistical programming language R, using both averages and developing negative binomial regression models that took into account factors at the document level, the author level, and the journal level.

As with our earlier study, reach is measured with downloads and attention, and impact is measured in citations: the number of downloads is taken from the Springer Nature servers according to COUNTER standards; attention is operationalised through Altmetric.com's Altmetric score; and citations from the Web of Science.

There are a wide range of other factors that can influence the impact and reach of research publications, besides their OA status. As with the previous two papers, predictive models were built to estimate the reach and impact that could be expected when taking into consideration some of these wider factors at the document, author, and journal level. Three negative binomial regression models were developed for making predictions about the number of citations, number of downloads, and the Altmetric score. Negative binomial regression models are suitable in each case as the dependent variables are all counts, with a variance that is higher than the mean. For each of the three dependent variables (citations, downloads, and Altmetric score), six variables were used in the model:

- Open access status
- Journal Impact Factor (JIF)
- Discipline of the journal
- *Times Higher Education* (THE) Institutional Ranking of corresponding authors' institutions
- Country of the institution
- Funder acknowledgement as a binary feature—either there was, or wasn't, a funder associated with the article

The OA status of the different publishing models was gathered from Dimensions, which in turn makes use of UnPaywall's OA typology.[12] Articles were classified into one of three categories:

Gold OA VOR (summarised as **Gold OA** in all tables): Immediate access on publication to the final published VOR for all, including any copyediting, typesetting, and any post-publication corrections. The VOR is published under an open licence (e.g. a Creative Commons CC BY licence)[13] which allows users to build on, adapt, and share articles. The costs of editorial and publishing processes are typically funded via an Article Processing Charge (APC) paid by the author's funder or institution.

Subscription VOR with earlier version available in a repository (summarised as **EarlyV** in all tables): A self-archived copy of an earlier article version, such as the AM or preprint, is available in a publicly accessible institutional or subject repository. The AM is

60,567
articles published in

1,262
SN hybrid journals

11. Academic Journals on nature.com (n.d.). Retrieved October 7, 2021 from https://www.springernature.com/gp/librarians/products/journals/academic-journals-on-nature-com

12. Piwowar. H. *et al.* (2018). *The state of OA: a large-scale analysis of the prevalence and impact of open access articles*. PeerJ 6, e4375. https://peerj.com/articles/4375/

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the version after peer review, but before copyediting, typesetting, or any post-publication corrections. It is usually made available after an embargo period, and rights for re-use are typically limited. The costs of editorial and publishing processes to validate and improve the manuscript are funded by subscriptions to the journal in which the final VOR is published.

Subscription VOR without earlier version available (summarised as **Non-OA** in all tables): All other subscription articles, including those shared only on an academic social network or illegally elsewhere. Subscribers to a journal have immediate access on publication to the final VOR.

Only those primary research articles where all the necessary metadata was available were included in the analysis:
- 138,449/157,333 (88%) of the articles were identified as being published in a journal with an impact factor
- 68,668/157,333 (44%) of the articles had a corresponding author that had an identifiable THE institutional ranking and country.

The overlap between these two factors left a final data set of 60,567 records incorporated in the analysis.

Table 1 shows the distribution of the 60,567 articles analysed in the study according to the different types of article classification.

Classification	Number of articles
Non-OA	44,557
EarlyV	8,350
Gold OA	7,660

Table 1: Number of articles according to classification

Part 1:
Overall results

This white paper presents findings that support our previous data[14] showing a clear advantage for articles published OA in hybrid journals compared to non-OA articles and, for the first time, evidence is seen for the distinct advantage for Gold OA articles compared to subscription articles with earlier versions available in a repository.

1.1 Citations

Looking at both average citations and the model predictions, an OA citation advantage can be seen for all OA articles; however the citation advantage is greatest for Gold OA (1.64 times higher than non-OA, or 2.12 times higher in the model) compared to subscription articles with an earlier article version available. Similarly, Wirsching et al.'s (2020) regression model predicted an advantage for Gold OA articles 1.53 times higher over non-OA articles in hybrid journals. Gold OA outperforms subscription articles with an earlier article version available (1.07 times higher over non-OA, or 1.17 times higher in the model). This confirms previous studies that have found a citation advantage for OA articles, whether within hybrid journals[15] or more widely.[16]

The citation advantage is greatest for Gold OA (1.64 times higher than non-OA) compared to EarlyV (1.07 times higher than non-OA)

Table 2: Average number of citations by article type

Access type	n	Mean	Mean (%)	Median	Prediction	Prediction (%)
Non-OA	44,557	5.80	100.00	4	5.88	100.00
EarlyV	8,350	6.18	106.59	4	6.87	116.90
Gold OA	7,660	9.52	164.18	6	12.46	211.87
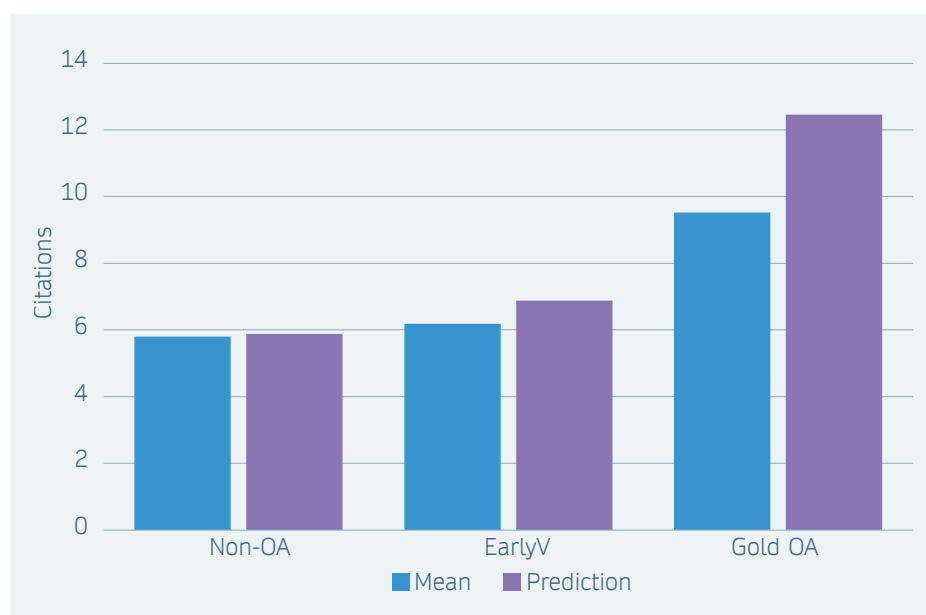
Figure 1: Average and predicted citations according to article type, showing the Gold OA citation advantage

14. Draux, H. *et al.* (2018)

15. Draux, H. *et al.* (2018)

16. Piwowar, H. *et al.* (2018)

1.2 Downloads

Gold OA delivers a significant advantage over non-OA, achieving 6.02 times higher downloads on average compared with non-OA (6.52 times as many downloads were predicted in the model).

Draux, Lucraft, and Walker (2018) previously found 3.2 times more downloads for Gold OA than non-OA in hybrid journals, with the model predicting 2.69 times the number of downloads for Gold OA than non-OA articles.

Measuring comparative downloads for subscription articles with an earlier article version available is limited, as our study only captures usage on Springer Nature platforms, rather than usage of those subscription articles in repositories. Therefore, a lower advantage is to be expected since only downloads of an article on the journal website are recorded.

However, while there may be usage elsewhere, such usage may be of a version less valued by researchers, according to the 2021 white paper *Exploring researcher preference for the version of record*[17] which found that researchers prefer to read and cite the final VOR. 83% of respondents preferred working with the final VOR for citing content in their own work, compared with 9% preferring AMs, and 2% preferring preprints.

Gold OA delivers a significant advantage over non-OA, achieving 6.02 times higher downloads on average

Table 3: Average number of downloads by article type, which continues to show a distinct Gold OA download advantage

Access type	n	Mean	Mean (%)	Median	Prediction	Prediction (%)
Non-OA	44,557	443.25	100.00	333	444.13	100.00
EarlyV	8,350	482.30	108.81	330	491.85	110.74
Gold OA	7,660	2,666.54	601.60	1730	2,894.66	651.76
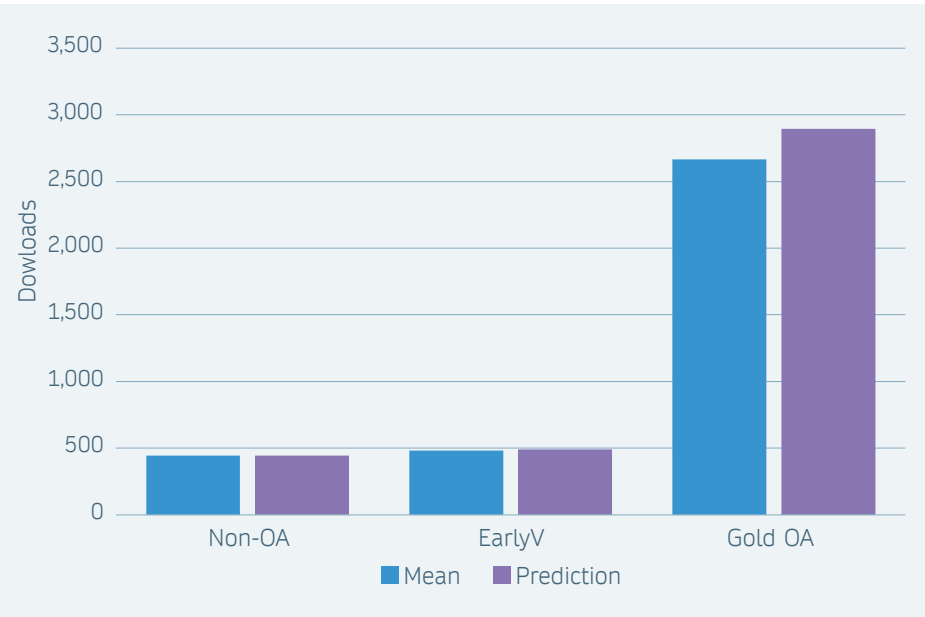
Figure 2: Average and predicted downloads according to article type, showing a distinct Gold OA download advantage

17. Lucraft, M. *et al.* (2021)

1.3 Altmetric Attention Score

Although there are known limitations in the use of altmetrics as a measure of impact,[18] there are still very significant differences in the average Altmetric score of OA articles over non-OA articles. Most notably, Gold OA has 4.91 times as high an Altmetric score as non-OA articles, while subscription articles with an earlier article version available have 2.10 times as high an Altmetric score as non-OA articles in hybrid journals.

The regression model predicted a greater advantage for Gold OA articles (6.88 times) over subscription articles with an earlier article version available (2.79 times), compared to non-OA articles in hybrid journals.

When considering the Altmetric scores for articles, it is important to recognise that the Altmetric score for most of these articles (62%) is in fact zero. Nonetheless, the differences in the average Altmetric score are still significant. Draux, Lucraft, and Walker (2018) previously found 2.4 times more attention for Gold OA over non-Gold OA in hybrid journals.

Gold OA has a significant advantage with 4.91 times as high an Altmetric score as non-OA, compared to EarlyV with 2.10 times as high as non-OA

Table 4: Average Altmetric Attention Score by article type, showing a distinct Gold OA Altmetric Attention Score advantage

Access type	n	Mean	Mean (%)	Median	Prediction	Prediction (%)
Non-OA	44,557	1.96	100.00	0	1.95	100.00
EarlyV	8,350	4.12	210.13	1	5.45	279.21
Gold OA	7,660	9.63	491.01	1	13.45	688.46
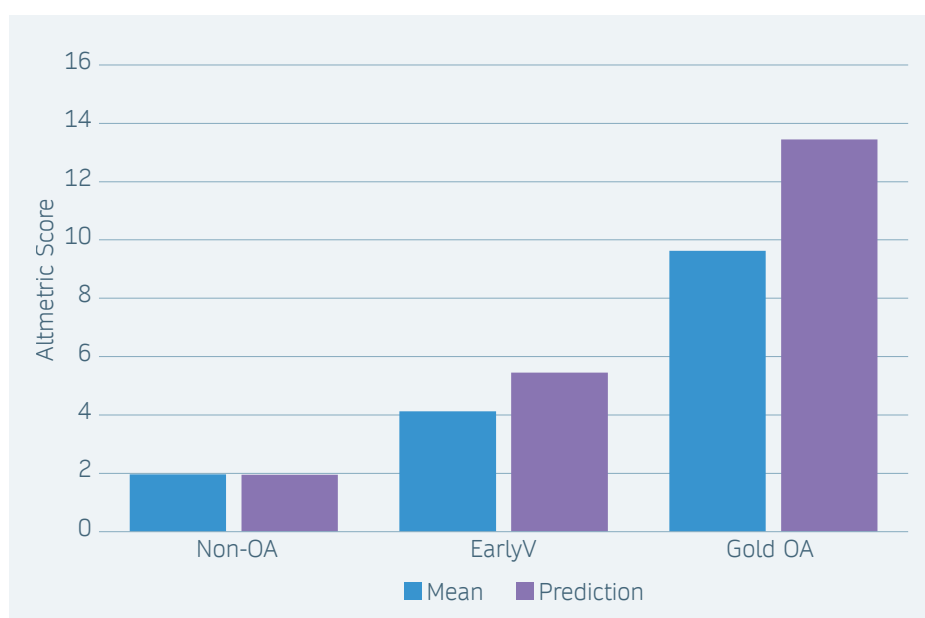
Figure 3: Average and predicted Altmetric Attention Score according to article type, showing a distinct Gold OA Altmetric Attention Score advantage

18. Thelwall, M. (2020). The pros and cons of the use of altmetrics in research assessment. *Scholarly Assessment Reports*, 2(1), 2. Retrieved October 7, 2021 from https://www.scholarlyassessmentreports.org/articles/10.29024/sar.10/

Part 2:
Discipline breakdown

Disciplinary differences are widely recognised in the prevalence of OA in different subjects,[19] as well as in citation behaviour,[20] downloads,[21] and Altmetric Attention Scores.[22]

The 60,567 articles in this study were attributed to 31 different discipline classifications that varied considerably in size. The largest, Medicine & Public Health, contained 9,986 articles. The smallest category (Science, Humanities and Social Science, multidisciplinary) contained just one article. Here we consider the six largest categories. These categories, which contained over 3,900 articles each, are: Medicine & Public Health; Engineering; Life Sciences; Chemistry; Mathematics; and Materials Science. This accounts for 35,740 of the 60,567 articles (59%).

Focusing again on the reach and impact through citations, downloads and Altmetric scores, although there is a wide variation by subject area, Gold OA articles outperformed both non-OA and subscription articles with an earlier article version available on all three measures in nearly every discipline, looking both at averages and predicted models.

In each of the six largest discipline categories there is a citation advantage for Gold OA compared to non-OA, ranging from 1.15 times to 3.61 times as many. Gold OA also outperforms subscription articles with an earlier article version available, the latter showing only 1.11 times to 1.89 times as many citations compared with non-OA.

For downloads, Gold OA articles always had more downloads across all subjects than either non-OA or subscription articles with an earlier article version available, ranging from 3.79 times to 6.13 times as many.

Typically there is a far larger Gold OA Altmetric score advantage over non-OA articles compared to subscription articles with an earlier article version available; however both Gold OA articles and subscription articles with an earlier article version have a large Altmetric score advantage over non-OA articles in every discipline.

Gold OA articles outperformed both non-OA and EarlyV on all three measures in nearly every discipline

19. Piwowar, H. *et al.* (2018)

20. Wilsdon, J. *et al.* (2015). *The metric tide: report of the independent review of the role of metrics in research assessment and management.* DOI: 10.13140/RG.2.1.4929.1363

21. Ortega, J.L. (2018). Disciplinary differences of the impact of altmetric. *FEMS Microbiology Letters*, 365, fny049. https://doi.org/10.1093/femsle/fny049

22. Htoo, T.H.H. & Na, J.-C. (2017) Disciplinary differences in altmetrics for social sciences, *Online Information Review*, 41 (2), 235-251. https://doi.org/10.1108/OIR-12-2015-0386; Ortega, J.L. (2018)

2.1 Citations

In each of the six disciplines there is a citation advantage for Gold OA compared to non-OA, although in the case of Materials Science it is only a predicted advantage. The Gold OA predicted citation advantage ranges from 1.15 times as many citations in Materials Science to 3.61 times as many in the Life Sciences. This outweighs the advantage for subscription articles with an earlier article version available, with only 1.11 times as many as non-OA in Mathematics to 1.89 times as many in Medicine & Public Health in the predictive model.

Gold OA articles typically have a higher citation advantage than subscription articles with an earlier article version available across all disciplines, although there is variation between subjects. In Life Sciences and Medicine & Public Health the Gold OA citation advantage is far larger than in Engineering, Mathematics, Chemistry and Materials Science (Table 5).

The advantage of subscription articles with an earlier article version available in Materials Science is primarily attributable to the skewed nature of citations and the relatively small sample size. This means that the results can be significantly influenced by the articles in one or two journals. For example, the advantage shown for articles with earlier versions seen in Materials Science is primarily attributable to its greater number of publications in the journal *Nano Research*; excluding all articles from that journal would mean that on average Gold OA articles were cited more often.

The split in citation advantage can also be seen in the prevalence with which the two groups have been found to share their research as OA. Piwowar *et al.* (2018) found Biomedical Research, Clinical Medicine, and Health to be three of the disciplines with the highest rate of OA, whilst Engineering and Technology, and Chemistry had the lowest rate of OA. Mathematics was also recognised as an area with a high proportion of OA, although it is also recognised as an area with low citation rates.

Table 5: Comparison of citations across different disciplines

Access type	Life Sciences		Medicine & Public Health		Engineering		Mathematics		Chemistry		Materials Science	
	mean (%)	pred (%)	mean (%)	pred (%)	mean (%)	pred (%)	mean (%)	pred (%)	mean (%)	pred (%)	mean (%)	pred (%)
Non-OA	100	100	100	100	100	100	100	100	100	100	100	100
EarlyV	117	117	138	189	121	120	111	111	113	123	108	127
Gold OA	232	361	178	286	138	142	118	135	117	134	99	115

2.2 Downloads

Unsurprisingly, across all subjects Gold OA articles always had more downloads than both non-OA and subscription articles with an earlier article version available, ranging from 3.79 times as many in Mathematics, to 6.13 times as many in Life Sciences. This can in part be attributed to the fact that downloads away from the journal website are not being counted.

Table 6: Comparison of downloads across different disciplines

Access type	Life Sciences		Medicine & Public Health		Engineering		Mathematics		Chemistry		Materials Science	
	mean (%)	pred (%)	mean (%)	pred (%)	mean (%)	pred (%)	mean (%)	pred (%)	mean (%)	pred (%)	mean (%)	pred (%)
Non-OA	100	100	100	100	100	100	100	100	100	100	100	100
EarlyV	115	109	120	145	142	117	96	107	152	123	119	121
Gold OA	613	771	527	681	605	555	379	520	472	511	463	503

2.3 Altmetric Attention Score

Both Gold OA articles and subscription articles with an earlier article version available have a large Altmetric score advantage over non-OA articles in every discipline, but typically there is a far larger Gold OA advantage, ranging from 3.57 to 6.60 times as many compared to 1.73 to 4.19 times as many for subscription articles with an earlier article version available. Although subscription articles with an earlier article version available show a slightly larger advantage in Chemistry, this disappears in the predictive model.

The largest Altmetric score advantage seen is for Gold OA articles in Mathematics with 6.6 times as many, or based on the predictive model, the Life Sciences has the largest advantage with 7.30 times as many. The lowest Altmetric score advantage comes from subscription articles, with an earlier article version available, in the Life Sciences with 1.73 times as many, or based on the predictive model, 2.17 times as many also for the Life Sciences.

Table 7: Comparison of Altmetric Attention Scores across different disciplines

Access type	Life Sciences		Medicine & Public Health		Engineering		Mathematics		Chemistry		Materials Science	
	mean (%)	pred (%)	mean (%)	pred (%)	mean (%)	pred (%)	mean (%)	pred (%)	mean (%)	pred (%)	mean (%)	pred (%)
Non-OA	100	100	100	100	100	100	100	100	100	100	100	100
EarlyV	173	217	265	388	261	349	419	266	423	357	291	395
Gold OA	394	730	357	633	430	575	660	427	397	412	470	538

Conclusion, limitations and recommendations

In setting out to update our earlier analysis of hybrid journals and the impact of OA, we wanted to better understand the continued advantage to those Springer Nature authors choosing immediate Gold OA, and to those who provide funding for Gold OA. Our findings show not only that Gold OA articles attract more citations, more downloads, and higher Altmetric Attention Scores on average, compared with non-OA articles, but for the first time we have also shown evidence of a stronger advantage for Gold OA compared to subscription articles with an earlier article version publicly available (e.g. AMs or preprints).

For citations, on average, subscription articles with an earlier article version available have 1.06 times more citations than non-OA articles. This is 1.64 times higher for Gold OA articles, and this was significantly higher in the predicted model used for this study.

As noted further below in Limitations, the downloads analysis should be treated with caution for comparing article types, as we are only able to analyse usage on the Springer Nature platform, which does not take account of usage elsewhere (e.g. in subject or institutional repositories or on other sharing sites). However, as with previous studies a strong advantage for OA articles is seen compared to non-OA, with 6.01 times more downloads for Gold OA articles.

For Altmetric analysis, again considering the limitations noted below, there are notable differences for OA articles compared to non-OA, with the advantage highest for Gold OA (4.91 times as high an Altmetric score on average), compared to subscription articles with an earlier article version available (2.10 times as high).

A stronger advantage for Gold OA compared with other access types, including Green OA, has not always been found in previous studies, although Piwowar *et al*. (2018) noted a stable citation impact for the period 2009 to 2015 for available Green OA compared to an increasing impact of Gold OA articles in hybrid journals over the same time period. The advantage shown in this analysis may indicate a continued trend for Gold OA articles in hybrid journals. However, it is difficult to separate correlation from causation for the effects seen. Although it is reasonable to assume that these journals contain content of a similar quality and standard regardless of publication model, it is possible that there remain systematic reasons why Gold OA articles have higher citations or attention. For example, it may reflect the likelihood of authors choosing their best work to publish OA, the likelihood of high profile funders to make funding for Gold OA available, or the likelihood that authors selecting Gold OA also have access to support or funding for wider promotion of the research post-publication. Certainly, we can relate the increased usage and citations of Gold OA to recent analysis of researcher preference for the final VOR. The availability of Gold OA VORs immediately on publication supports the researcher preference we found, with 83% of respondents who preferred working with the final VOR for citing content in their own work, compared with 9% preferring AMs.[23]

Although we see a wide variation in the level of advantage by subject area, Gold OA articles outperformed both non-OA and subscription articles with an earlier article

For the first time we have shown evidence of a stronger advantage for Gold OA compared to subscription articles with an earlier article version publicly available e.g. AMs

23. Lucraft, M. *et al*. (2021)

version available on all three measures in nearly every discipline, looking both at averages and predicted models. This is strongest in Life Sciences, with 2.32 times as many citations as non-OA, compared to 1.16 times as many citations for subscription articles with an earlier article version available compared to non-OA. The noted variation across subjects supports previous analysis undertaken looking at discipline trends, and may be seen to reflect community norms in sharing and using different article types (Piwowar and colleagues found more than half of all publications were available openly in Biomedical Research and Mathematics, compared to less than 20% in Chemistry and Engineering).

Limitations

There remains wide criticism for the methodologies used across citation advantage studies.[24] Whilst we have attempted to remove confounding factors (such as author or journal prestige) within the predicted modelling, it is impossible to control for all causation as noted above. There are inevitably factors that are not incorporated into the model or analysis that are likely to explain certain behaviours, and where these factors are at a journal level it may impact hundreds of articles with the same OA policy. There may also be implications from the data sampling, as only those articles where all the necessary metadata was available were included in the analysis. As journals without a JIF, and institutions without a THE ranking were excluded, this might also have an impact on the results.

In addition, the samples used for this study represent only articles published by Springer Nature, without random sampling, and only represent a single year of publication (2018). The highly skewed nature of citations and Altmetric scores also means that one or two articles can have a disproportionately large influence over the mean, even for larger data sets. A different set of articles across a broader cross-section of publishers may show greater or lesser evidence for an OA advantage, even if using the same methodology.

Measuring comparative downloads is limited as our study only captures usage on our platforms, rather than usage of subscription articles with an earlier article version available in repositories, so the lower advantage of these earlier versions compared with Gold OA is to be expected as only downloads of an article on the journal website are recorded. However, while there may be usage elsewhere, such usage is of an article version we believe to be less valued by researchers, as researchers prefer to read and cite the final VOR article.[25]

There are also further questions on the accuracy of the classifications. To what extent can we trust the proportion of Green OA articles included in the classification of 'subscription articles that have earlier article versions available', considering likely differences in coverage of OA repositories? All of these limitations mean that it is important to consider trends and general directions in the data, rather than minute differences.

24. Piwowar, H. *et al.* (2018)

25. Lucraft. M. *et al.* (2021)

Recommendations

As an update to our previous large scale analysis of hybrid articles, we have provided evidence of not only an OA advantage, but importantly an advantage for full Gold OA over subscription articles with earlier article versions available, including AMs via subscription-tied Green OA. Subject to the limitations noted, we believe that this presents a robust case for continued funding and investment from funders for full and immediate Gold OA articles in hybrid journals. For Springer Nature authors who have selected the Gold OA publishing route, there is clear evidence that their work has benefitted from increased attention and reach. Although not the focus of this study, a previous analysis published in 2020[26] also showed that OA publications are reaching a broader community of readers, beyond academia, and around the world showing OA can achieve increased equitable access to research. Together, these findings showcase the success from investments in Gold OA for hybrid journals.

The introduction of policies which restrict funding for OA publishing in hybrid and TJs is counterproductive. Enabling their funding via TAs is helpful, but since many authors and organisations are not yet covered by TAs, this route is insufficient by itself and needs to be supported with other transitionary funding measures. Efforts which seek to increase the availability of Green OA don't create the intended benefits and risk delaying or even preventing the take up of full Gold OA and achieving the benefits described above. While sharing of subscription-tied earlier versions can help the dissemination of research, they do not have as strong a reach or impact as full Gold OA, and remain dependent on the continuation of subscription models to fund the costs of editorial and publishing processes to validate and improve the manuscript. As such, we believe investment in Gold OA should be a priority and is the only way to achieve full, immediate and sustainable OA.

This white paper presents a robust case for continued funding and investment from funders for full and immediate Gold OA articles in hybrid journals

26. Pyne, R. *et al.* (2020). *Diversifying readership through open access: A usage analysis for OA books* [White paper]. Springer Nature. Retrieved October 7, 2021 from https://www.springernature.com/gp/open-research/journals-books/books/diversifying-readership-through-open-access; Wirsching, H. *et al.* (2020)

Acknowledgements

Appendices

A1. Box plots

Figure 4: Box plot showing the number of citations for different access types across all articles. There is a clear citation advantage for Gold OA[27]
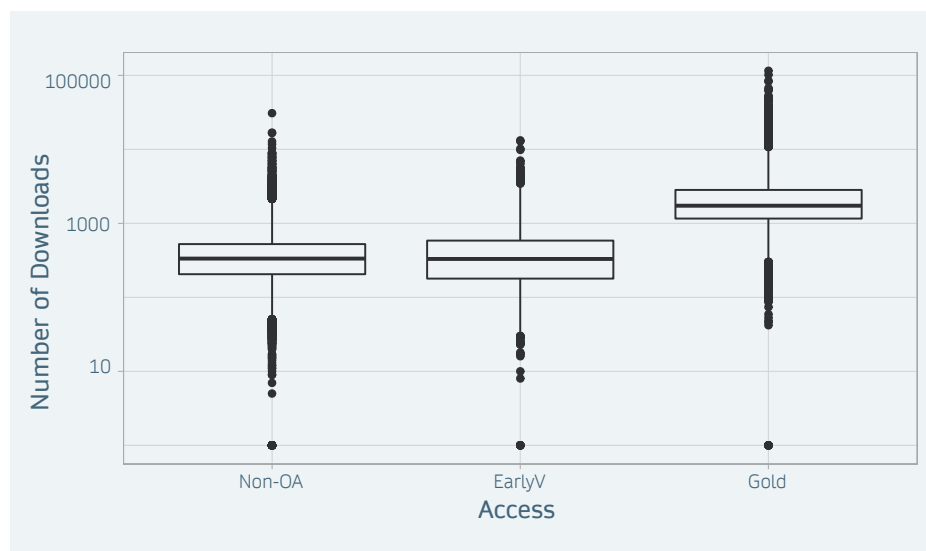
Figure 5: Box plot showing the number of downloads by article type, with a distinct Gold OA download advantage

27. Where a logarithmic scale is used in a visualisation, all zero-counts have been changed to 1 so that they are included in the visualisation.
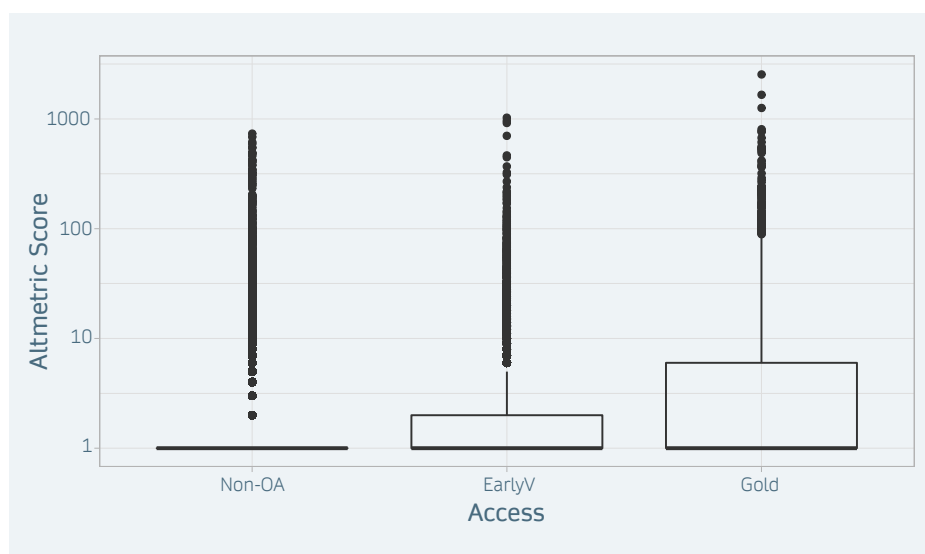
Figure 6: Box plot showing the Altmetric Attention Score by article type, with a distinct Gold OA Altmetric Attention Score advantage

A2. Discipline breakdowns

1. Medicine & Public Health

In Medicine & Public Health, the average and predicted number of citations, downloads, and Altmetric score follows the overall trends of the study. There are predicted to be distinct citation advantages over non-OA for both articles with earlier versions available (189%) and Gold OA (286%). Similarly, there is an Altmetric score advantage over non-OA for both articles with earlier versions available (388%) and Gold OA (633%), and the predicted download advantage is particularly pronounced for Gold OA over non-OA (681%).

Table 8: Average and predicted citations for Medicine & Public Health, showing a clear OA citation advantage

1.1 Citations in Medicine & Public Health

Access type	n	Mean	Mean (%)	Median	Prediction	Prediction (%)
Non-OA	6,744	6.70	100.00	5	7.20	100.00
EarlyV	1,358	9.27	138.49	6	13.64	189.29
Gold OA	1,884	11.89	177.57	8	20.60	285.94
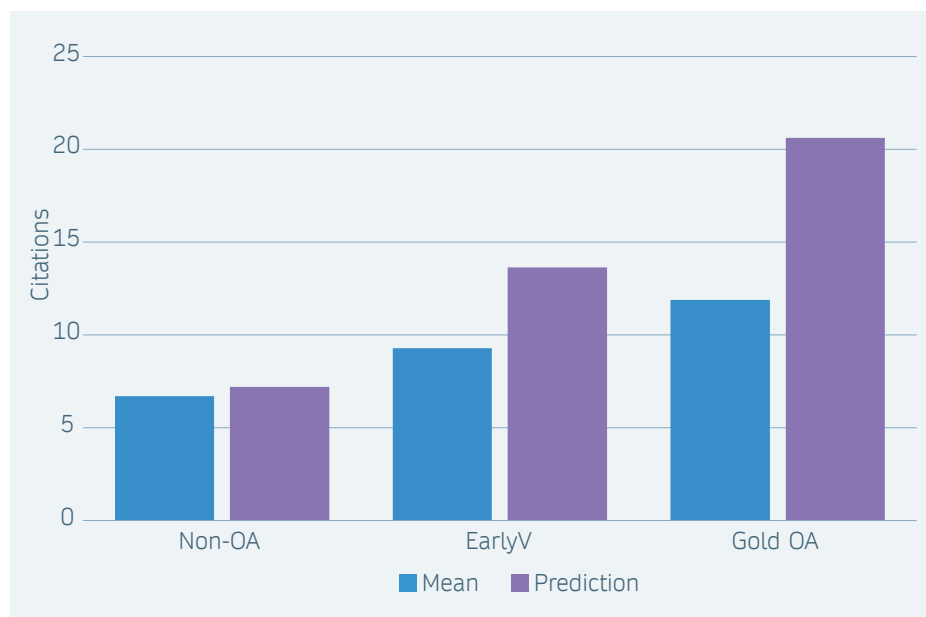
Figure 7: Bar chart showing mean and predicted citations for Medicine & Public Health, showing a clear OA citation advantage

1.2 Downloads in Medicine & Public Health

Table 9: Average and predicted downloads for Medicine & Public Health, showing a clear OA advantage, particularly for Gold OA

Access type	n	Mean	Mean (%)	Median	Prediction	Prediction (%)
Non-OA	6,744	513.07	100.00	399.5	515.59	100.00
EarlyV	1,358	614.37	119.74	469	748.40	145.15
Gold OA	1,884	2,704.83	527.18	1781	3509.22	680.62
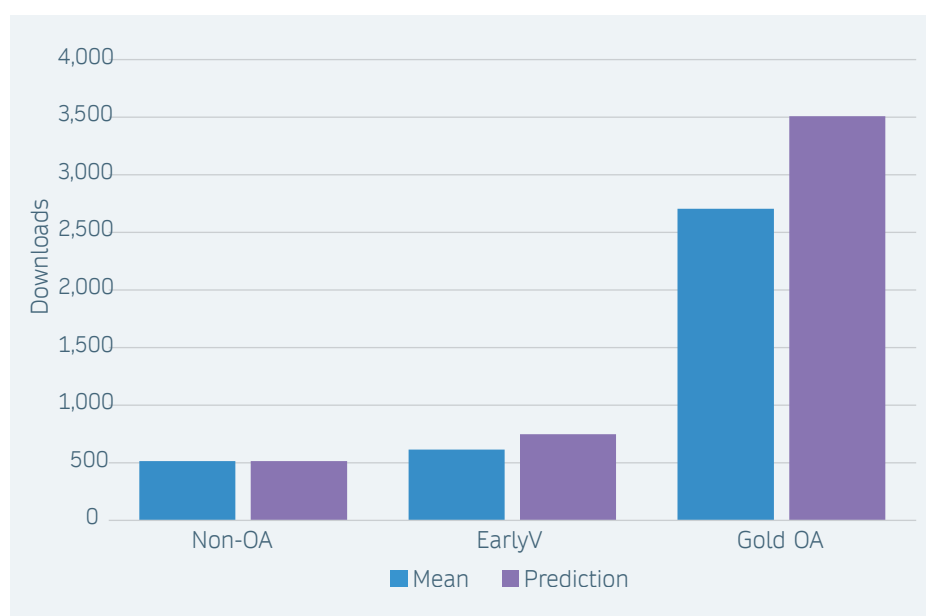
Figure 8: Bar chart of mean and predicted downloads for Medicine & Public Health, showing a clear OA advantage, particularly for Gold OA

1.3 Altmetric Attention Score in Medicine & Public Health

Access type	n	Mean	Mean (%)	Median	Prediction	Prediction (%)
Non-OA	6,744	3.52	100.00	1	3.64	100.00
EarlyV	1,358	9.32	264.92	2	14.14	388.06
Gold OA	1,884	12.57	357.40	2	23.08	633.19
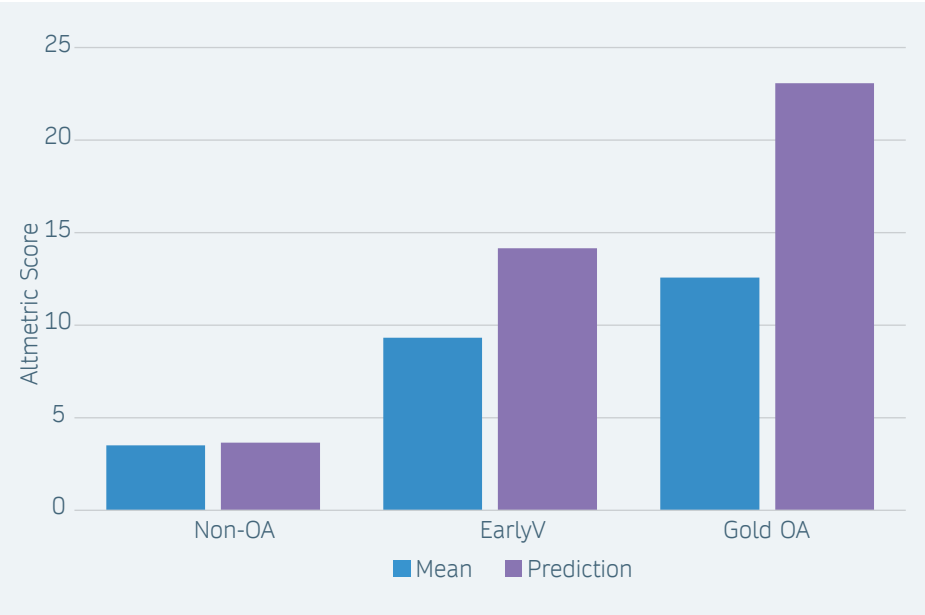
Figure 9: Bar chart of mean and predicted Altmetric Attention Scores for Medicine & Public Health, showing large actual and predicted Altmetric Attention Score advantages, particularly for Gold OA

2. Engineering

Engineering has relatively little variation in the number of citations across the different access types, although it still follows the typical pattern of Gold OA having a greater predicted citation advantage (142%) and Altmetric score advantage (575%) over non-OA than its predicted citation advantage for articles with an earlier version (120%) and Altmetric score advantage (349%). The Gold OA download advantage (555%) is many times the size of the advantage for articles with an earlier version (117%).

2.1. Citations in Engineering

Access type	n	Mean	Mean (%)	Median	Prediction	Prediction (%)
Non-OA	6,086	5.77	100.00	4	5.71	100.00
EarlyV	469	7.00	121.33	5	6.85	119.92
Gold OA	400	7.98	138.28	5	8.08	141.58
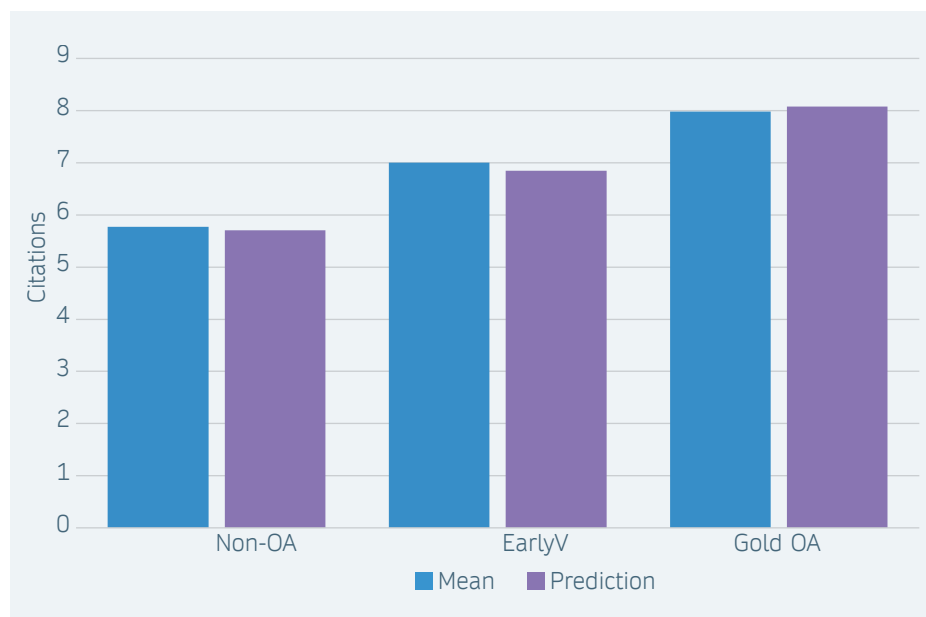
2.2. Downloads in Engineering

Access type	n	Mean	Mean (%)	Median	Prediction	Prediction (%)
Non-OA	6,086	310.05	100.00	235	311.44	100.00
EarlyV	469	438.93	141.57	345	364.04	116.89
Gold OA	400	1,874.82	604.68	1,418.5	1,729.67	555.37
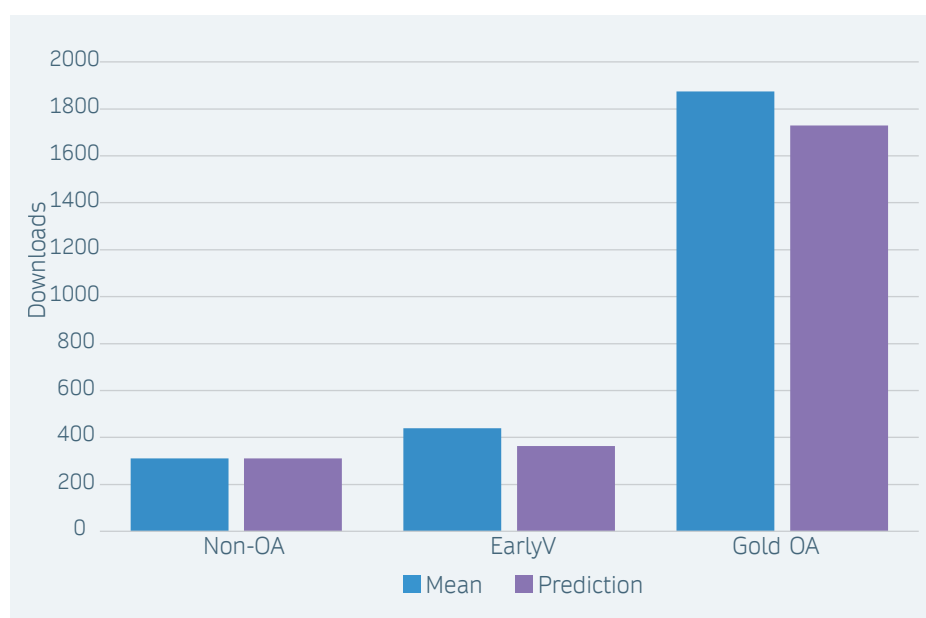
2.3. Altmetric Attention Score in Engineering

Access type	n	Mean	Mean (%)	Median	Prediction	Prediction (%)
Non-OA	6,086	0.29	100.00	0	0.22	100.00
EarlyV	469	0.75	261.32	0	0.76	349.16
Gold OA	400	1.23	430.35	0	1.25	575.25
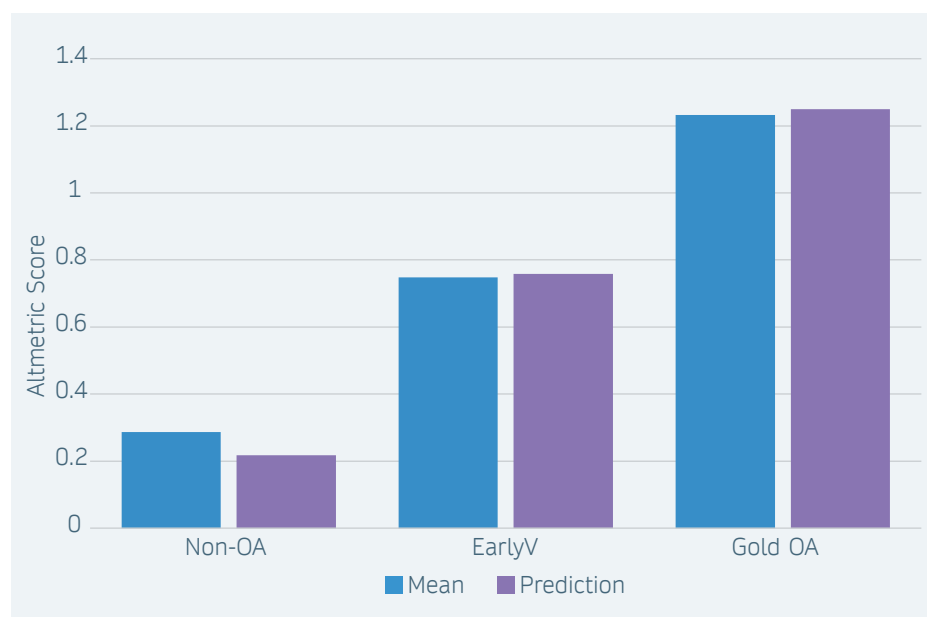
3. Life Sciences

Life Sciences is a discipline with a high Gold OA advantage, the largest of any of the six disciplines, with 2.32 times as many citations as non-OA articles. Nonetheless, this still falls short of the prediction of the model of 3.61 times as many citations that might be typically expected from a similar set of articles.

There is also a large Altmetric score advantage—the highest predicted Altmetric score advantage of any of the disciplines—at 7.29 times as high as non-OA. The actual average was 3.94 times as high.

Gaps between the size of the average and predicted average are expected as smaller samples are taken from a skewed sample, and the predictive model softens the likelihood of unexpected results in the sample.

3.1. Citations in Life Sciences

Access type	n	Mean	Mean (%)	Median	Prediction	Prediction (%)
Non-OA	4,883	5.63	100.00	4	5.69	100.00
EarlyV	447	6.56	116.64	5	6.66	117.15
Gold OA	841	13.06	232.05	8	20.53	361.03
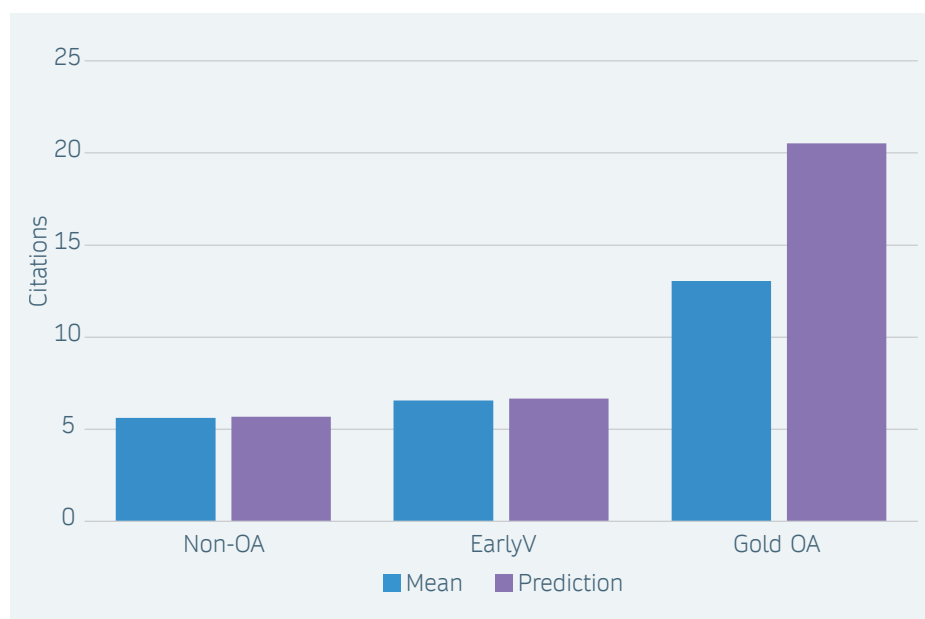
Figure 13: Bar chart of mean and predicted citations for Life Sciences, showing a large Gold OA citation advantage

Table 15: Average and predicted downloads for Life Sciences, showing a large Gold OA download advantage, and a far smaller advantage for EarlyV, over non-OA
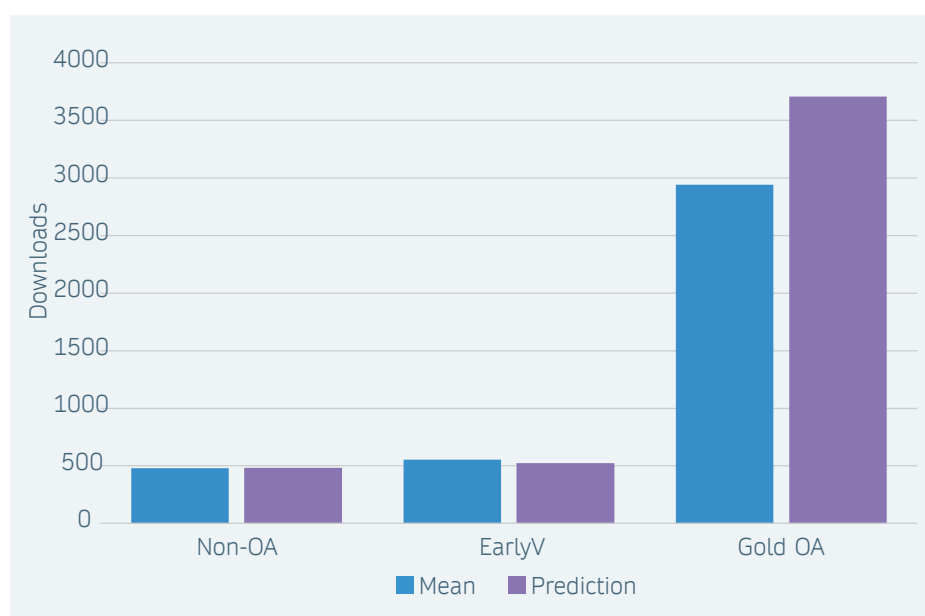
3.2. Downloads in Life Sciences

| Access type	n	Mean	Mean (%)	Median	Prediction	Prediction (%)
Non-OA	4,883	479.54	100.00	403	481.17	100.00
EarlyV	447	553.66	115.46	456	524.02	108.90
Gold OA	841	2,941.44	613.39	2,037	3,707.62	770.53

Figure 14: Bar chart showing mean and predicted downloads for Life Sciences, showing a large Gold OA download advantage, and a far smaller advantage for EarlyV, over non-OA

3.3. Altmetric Attention Score in Life Sciences

Access type	n	Mean	Mean (%)	Median	Prediction	Prediction (%)
Non-OA	4,883	3.28	100.00	1	3.40	100.00
EarlyV	447	5.66	172.73	1	7.40	217.29
Gold OA	841	12.93	394.36	3	24.83	729.68
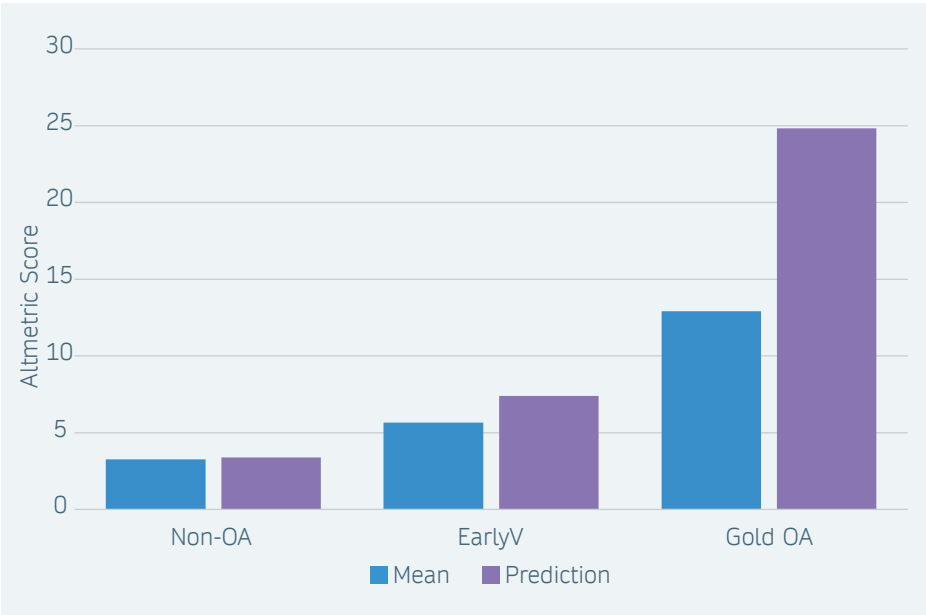
4. Chemistry

The model predicts a Gold OA citation advantage (134%) over both articles with an earlier version (123%) and non-OA (100%) in Chemistry.

The Altmetric score advantage over non-OA articles is lower for Gold articles (397%) than for articles with an earlier version (423%), although this advantage disappears in the predictive model.

4.1. Citations in Chemistry

Access type	n	Mean	Mean (%)	Median	Prediction	Prediction (%)
Non-OA	4,064	6.01	100.00	4	5.86	100.00
EarlyV	269	6.79	112.89	5	7.20	122.90
Gold OA	394	7.05	117.30	5	7.85	133.93
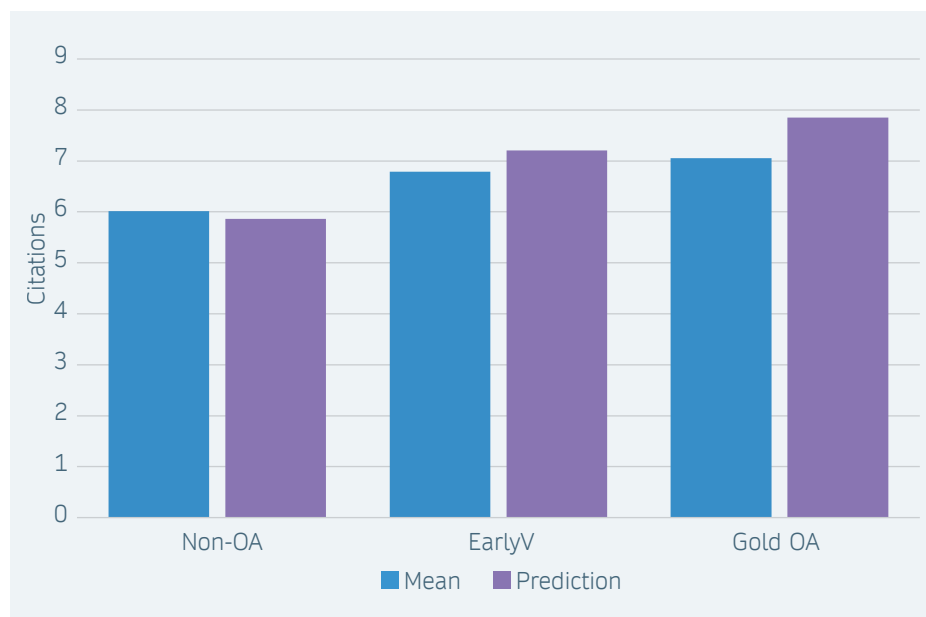
Figure 16: Bar chart of mean and predicted citations for Chemistry, showing the citation advantage of Gold OA over both EarlyV and non-OA

4.2. Downloads in Chemistry

Table 18: Average and predicted downloads for Chemistry, showing a clear Gold OA download advantage

Access type	n	Mean	Mean (%)	Median	Prediction	Prediction (%)
Non-OA	4,064	368.56	100.00	298.5	363.90	100.00
EarlyV	269	561.03	152.22	448	445.90	122.53
Gold OA	394	1,740.94	472.36	1,400.5	1,859.55	511.00
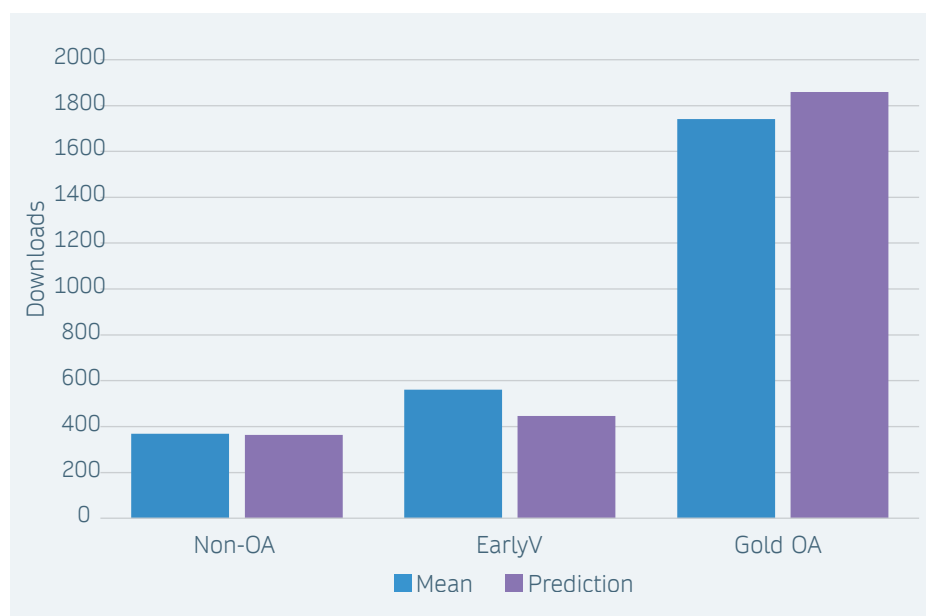
Figure 17: Bar chart of mean and predicted downloads for Chemistry, showing a clear Gold OA download advantage, and a smaller advantage for EarlyV, over non-OA

4.3. Altmetric Attention Score in Chemistry

Access type	n	Mean	Mean (%)	Median	Prediction	Prediction (%)
Non-OA	4,064	0.51	100.00	0	0.44	100.00
EarlyV	269	2.14	422.93	0	1.58	356.87
Gold OA	394	2.01	396.72	0	1.82	411.61

5. Mathematics

Mathematics is another field with a low Gold OA citation advantage, although the Gold citation advantage (118%) is higher than the citation advantage for articles with an earlier version (111%), with an even higher advantage predicted in the model (135%).

There is a more notable Altmetric score advantage predicted over non-OA for Gold OA (427%) than for alternative versions (266%), although both are large.

5.1. Citations in Mathematics

Access type	n	Mean	Mean (%)	Median	Prediction	Prediction (%)
Non-OA	1,717	2.63	100.00	1	2.48	100.00
EarlyV	1,830	2.92	111.20	2	2.76	111.27
Gold OA	418	3.09	117.61	2	3.34	134.90
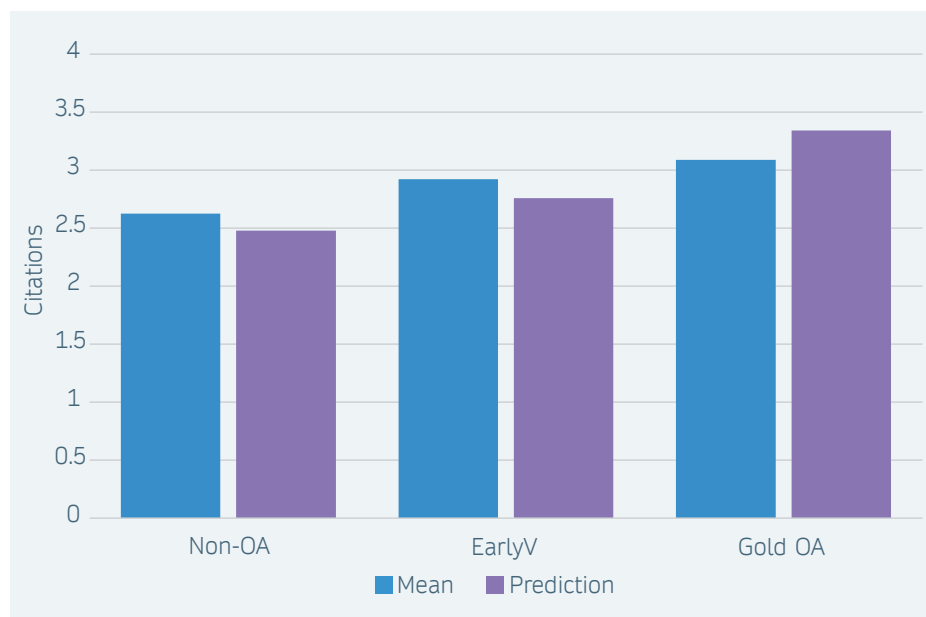
Figure 19: Bar chart of mean and predicted citations for Mathematics, showing the OA citation advantage to be higher in Gold OA than for EarlyV

Table 21: Average and predicted downloads for Mathematics, showing a clear Gold OA download advantage over non-OA, and a smaller predicted advantage for EarlyV
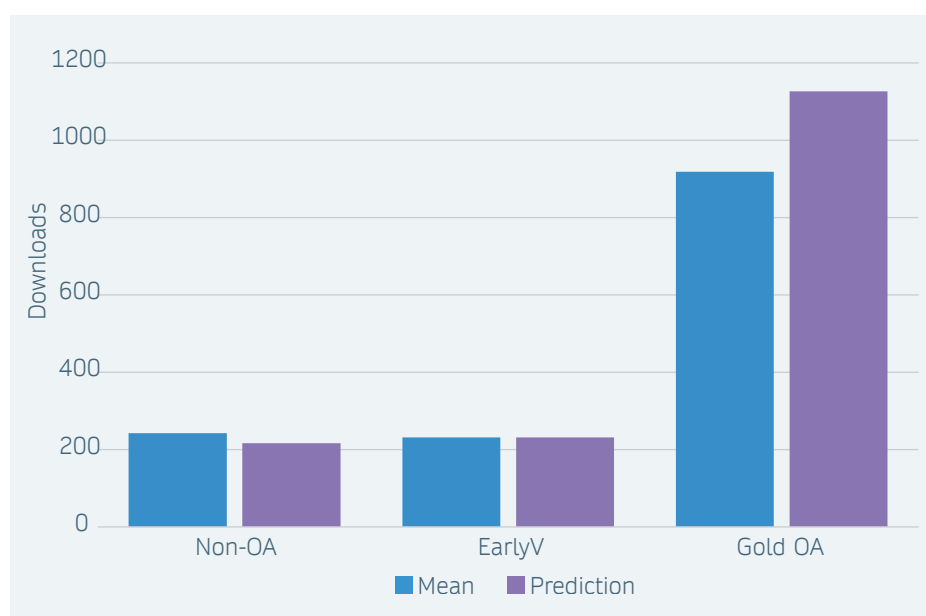
5.2. Downloads in Mathematics

Access type	n	Mean	Mean (%)	Median	Prediction	Prediction (%)
Non-OA	1,717	242.44	100.00	182	216.53	100.00
EarlyV	1,830	231.83	95.63	172	231.82	107.06
Gold OA	418	918.83	379.00	838.5	1,126.60	520.29

Figure 20: Bar chart of mean and predicted downloads for Mathematics, showing a clear Gold OA download advantage

5.3. Altmetric Attention Score in Mathematics

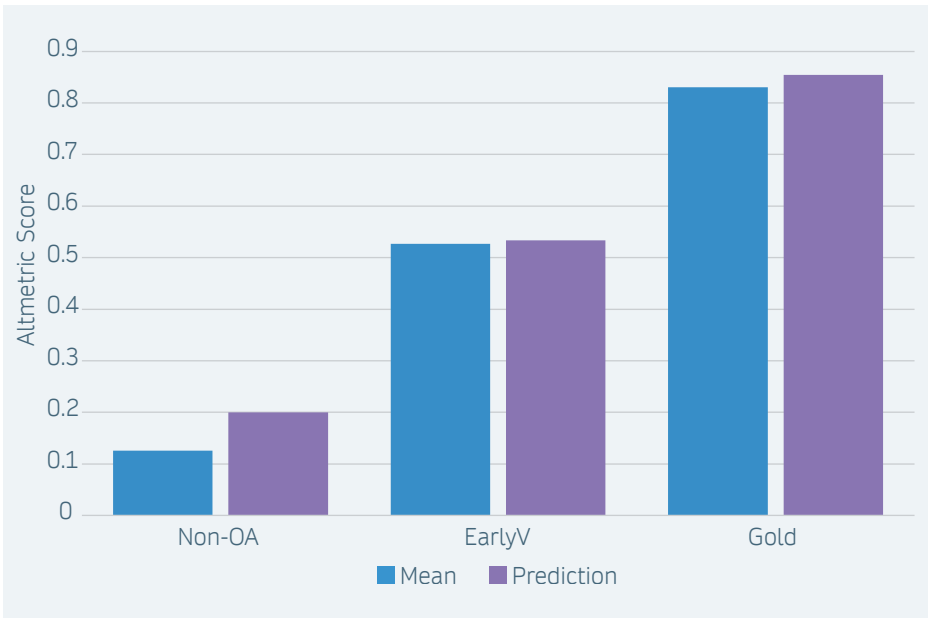| Access type	n	Mean	Mean (%)	Median	Prediction	Prediction (%)
Non-OA	1717	0.13	100.00	0	0.20	100.00
EarlyV	1830	0.53	418.74	0	0.53	266.40
Gold OA	418	0.83	659.89	0	0.85	426.93

Figure 21: Bar chart of mean
and predicted Altmetric
Attention Score for
Mathematics, showing the
expected Gold OA Altmetric
Attention Score advantage over
EarlyV and non-OA

6. Materials Science

Materials Science is a discipline with a low citation advantage, with a smaller Gold OA advantage in the actual results (99%) than non-OA (100%), although the predicted advantage is higher (120%).

There is also a large predicted Altmetric score advantage for Gold OA (538%) in comparison to articles with an earlier version (395%) and non-OA (100%).

6.1. Citations in Materials Science

Access type	n	Mean	Mean (%)	Median	Prediction	Prediction (%)
Non-OA	3,556	5.97	100.00	4	6.30	100.00
EarlyV	167	6.47	108.43	4	7.99	126.88
Gold OA	213	5.94	99.48	5	7.21	114.51

6.2. Downloads in Materials Science

Access type	n	Mean	Mean (%)	Median	Prediction	Prediction (%)
Non-OA	3,556	370.44	100.00	297	382.08	100.00
EarlyV	167	441.35	119.14	360	462.34	121.01
Gold OA	213	1,715.85	463.20	1,462	1,923.73	503.49

6.3. Altmetric Attention Score in Materials Science

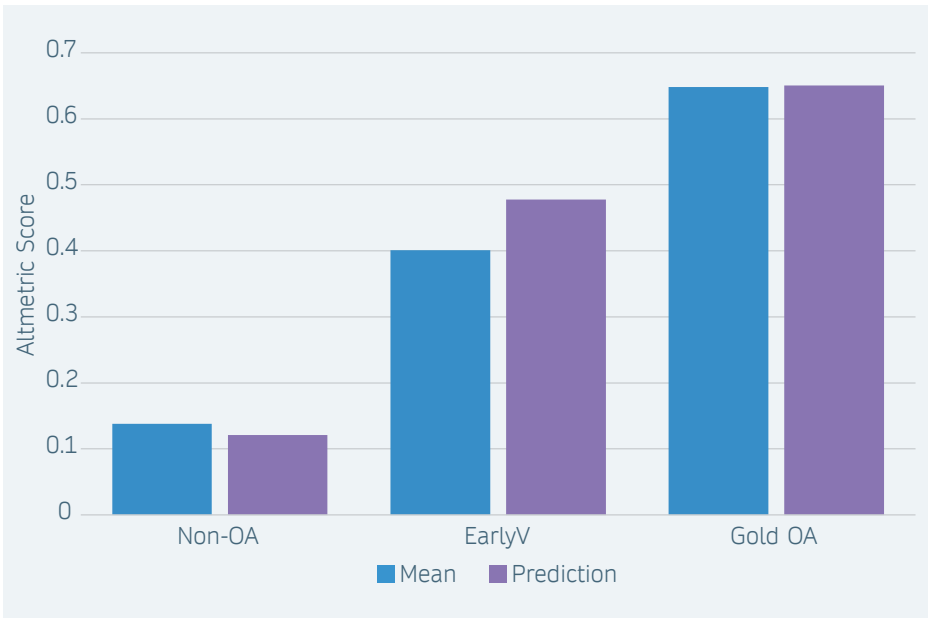| Access type	n	Mean	Mean (%)	Median	Prediction	Prediction (%)
Non-OA	3,556	0.14	100.00	0	0.12	100.00
EarlyV	167	0.40	291.15	0	0.48	394.90
Gold OA	213	0.65	470.18	0	0.65	537.56

Figure 24: Bar chart of mean and Altmetric Attention Score for Materials Science, showing a clear Gold OA advantage and a smaller advantage for EarlyV

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Around our complex and interconnected world, the research community is advancing discovery for all of us. These illustrations celebrate some of the great minds who have helped advance discovery through history.
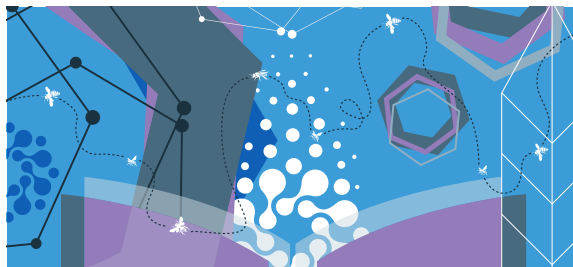
Jean-Claude Bradley (1969–2014)

Jean-Claude Bradley was a chemist and passionate proponent of Open Science. Following an early career in patent driven nanotechnology, Bradley came to believe that the work he was doing wasn't having the impact or benefitting mankind in the way he had hoped. At Drexel University, working on antimalarials, he coined the term Open Notebook Science for an approach which aimed to make the details and raw scientific data of every experiment done in the lab freely available within hours of production. Bradley was founding Editor-in-Chief of *Chemistry Central Journal* and a founding Editor of the *Journal of Cheminformatics*. In 2007 he was awarded a Blue Obelisk award for achievements in promoting Open Data, Open Source and Open Standards.

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