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Altmetric 'mentions' and the identification of research impact

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Abstract

Can data emerging from media 'mentions' of research provide timely indicators of outcomes linked to social and technical innovation for stakeholders in networks beyond academia? Altmetric.com has collated mentions pointing at 2.5 million scholarly documents. Articles from high impact journals have a high average mention count, but those with more mentions do not always have more citations. There are professional, academic and social motivations for mentions: the challenge is to discern patterns and concentrations that capture these factors. Do mentions have innovative value in communicating impact beyond the academic world? Impact in communities of practice. Rapid and accessible communication of innovative research outcomes relevant to practitioners and professionals in the health sector is also of value to research users and managers. We interviewed a range of experts but found no clear characteristics of research publications with economic, social or professional - rather than academic - impact. Analysis confirmed many motivations for research mentions and highlighted their communication potential, but found no consistent view as to why some articles get mentioned frequently. Impact in communities of interest. Patients, carers and supporters of disease charities represent a network that wants to look at, understand and communicate research about new treatments. Statistical analysis showed more mentions were given to papers associated with diseases tackled by charities with larger research funds. Cardiovascular disease receives more attention than its charitable research spend suggests, however, whereas spend on Immune and Musculo-skeletal diseases is high but media mentions are relatively low. Health/clinical networks can enable timely, rapid and 'serious' media communication of innovative research with non-academic social and professional stakeholder benefits, but they may need key people as active nodes to engage them.

We'd like to thank Ian Calvert at Digital Science for help with linking altmetric and Medline document records. Corresponding Author: Tamar Loach, Digital Science, The Macmillan Building, 4 Crinan Street, London, N1 9XW, t.loach@digital-science.com.

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Altmetric mentions and the identification of research impact

The client's objectives

Nesta aims to boost innovation potential and supports projects to provide novel insights into how scientific or technical areas emerge. Historically, databases of academic journal articles – and to a lesser extent patents – have been key to tracking the dynamics of science and technology. Now, alternative metrics for understanding scholarly impact are available. A Nesta working paper 13/09 looked at a range of tools used to explore emerging technologies. It concluded that while an increasing number of tools can model technology trends, these are not yet useful for decision-making.[1]

The globalization of scientific research and technology development means that high-impact technical capabilities emerge in increasingly diverse social, economic and physical geographies and often extend beyond any national jurisdiction.[2] For Government policy makers and business strategy alike there is a need for a reliable horizon scanning capability. Nesta therefore sought proposals for experimental ideas to develop novel analytic tools, to use novel data sources and to combine existing resources to provide better answers to questions asked by technology investors and policy makers.

The project

It is generally assumed that 'excellent' research is likely to make a greater contribution to innovation than mediocre research. Problems arise, however, in determining what research is excellent, making that determination in a timely fashion, and establishing whether the outcomes of that research are primarily of academic research interest or more directly linked to innovation. This project makes use of data emerging from social and mainstream media mentions of research publications. These appear much more rapidly than conventional academic citations and are generated by a wider range of users. They therefore offer the potential for early and complementary indicators of the 'impact' of a piece of research. Such indicators could be valuable in identifying innovation seen as significant by stakeholders in networks beyond academia.

The consultants

Digital Science is a business unit of Macmillan Publishers Ltd. It supports a growing range of analytical capabilities drawing on a diversity of data within and emerging from the research process. As well as Altmetric.com (on social and mainstream media attention to research publications), the portfolio companies include ÜberResearch (on funding), ReadCube (on publication content), fig**share** (on data, tables and figures within publications), BioRAFT (research management, compliance and productivity), LabGuru (on laboratory management) and Symplectic (on research management information). It has more recently established a consultancy capability led by Dr Jonathan Adams, formerly Director of Research Evaluation at Thomson Reuters and founder of UK-based consultancy *Evidence* Ltd.

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[1] http://www.nesta.org.uk/publications/quantitative-analysis-technology-futures-part-2

[2] Adams, J. (2012). Collaborations: the rise of research networks. Nature, 490, 335-336. Adams, J (2013). The fourth age of research. Nature, 497, 557-560.

Background

Formal research evaluation methods have focussed on academic research and outcomes, principally because a declining resource base for public research in the 1980s – following the global oil crisis in the 1970s – required greater selectivity and the need for more transparent assessment. Since a common aim of academic research is to publish the outcomes, publication analysis became a frequent objective. This was particularly marked in the Netherlands and the UK, which led the way in the development of systematic research assessment. Since each publication referenced, or cited, relevant prior knowledge, more frequently cited outputs came to be seen as having greater 'impact'. Thus, citation analysis came into widespread use by research funders and managers. Citation analysis is made easier because there are well developed commercial databases that index new research publications and that link older and newer literature through their citations. This provides individual citation counts and average citation benchmarks.

Citation analysis has serious limitations in its utility for policy and management applications. It has been thoroughly researched and is now widely accepted in academic research evaluation, as a supporting indicator if not as a direct metric in itself. It needs careful calculation and interpretation, however, particularly for small samples. It is not timely for managing research projects because citations accumulate over years. And while citations may indicate academic impact they are not proven to be any indicator of social or economic impact.

Substitutes – or supplements – to citation analysis are therefore required. The agenda for evaluating research outcomes has always been wider than academic excellence alone, but recently has shifted in emphasis towards research outcomes with social benefits and links to innovative processes and products. If supplementary indicators were also more immediate, and identified significant outputs soon after completion, then they would be of great value.

Altmetrics as a complement to conventional bibliometrics

New sources of social communication provide large volumes of data from which informative and timely signals can be extracted. For example, Boston-based Recorded Future has used the analysis of Twitter feeds to predict the timing and location of protest events around major Government-level meetings and cyber-attacks on financial organisations.[3]

Could data sources in social and mainstream media be used to extract signals of the significance of research publications? If so, they would certainly be more timely than citations and could be complementary in the kind of significance – or impact – that they reference.

The altmetric concept (as 'alternative metrics' to traditional citation metrics) has been promoted by Jason Priem, the co-author in 2010 of the altmetrics manifesto.[4] He argued that altmetrics can expand our view of impact and of what is creating the impact by sharing raw datasets, code, and experimental designs, through semantic publishing (where the citable unit is a phrase rather than an article) and via blogging, microblogging, and comments or annotations on existing work. He argued that altmetrics' diversity would help in measuring the aggregate impact of the research enterprise itself.

However, despite many claims from multiple academic analysts, specific indicators that clearly identify a specific aspect of a publication remain somewhat elusive. There are both contradictory and confirmatory reports for many proposed metrics. (Below, we look at what drives Altmetric mentions and conventional citations.)

In the USA, NISO (the National Information Standards Organisation) is leading an Alternative Assessment Metrics Project to collate input from diverse, international stakeholders and identify key requirements and potential action on many aspects of metrics and assessment.[5] This includes the development of specific definitions for alternative assessment metrics, identifying appropriate output types and exploring their relationships with known metrics. The project also seeks to agree statements around the role of and standards for alternative assessment metrics in research evaluation.

Altmetric.com is a key commercial source of systematically indexed and collated data from social media and from mainstream media that reference or 'mention' (cf. 'citation') research publications.[6]

WHAT IS A MENTION?

Mentions are the altmetric equivalent of the citation in conventional bibliometrics.

A mention is the identification of a publication (such as a journal article) with or without additional commentary in a non-academic medium.

Mentions can be collated from sources among both mainstream (e.g. newspapers, broadcast) and social (e.g. Twitter, Facebook walls, blogs) media.

A score or index can be created from collated mentions by applying a weighted formula.

[3] https://www.recordedfuture.com/
[4] http://altmetrics.org/manifesto/
[5] http://www.niso.org/news/pr/view?item_key=0051dd6c2ee7962b1bd3cc35059326e1fafb2b00
[6] Altmetric data are available through the company's open API at api.altmetric.com

A number of academic studies have recently made use of Altmetric data that mention research journal articles. (In this report 'Altmetric' refers to the company and 'altmetric' refers to the generic concept). Two of those academic studies provided key input to this project.

Tim Evans and Tamar Loach (Complexity and Networks Group, Imperial College, London) analysed counts of mentions linked to particular journals. They compared the average number of mentions[7] to articles in a specific journal with the Thomson Reuters 'impact factor' of that journal. The 'impact factor' is a journal-level index of the average number of times articles have been cited in recent years. It is controversial because of its misuse in research evaluation but it unequivocally points to journals with high average citation rates, like *Nature* and *Science*, that are agreed to have international status.

Not all articles receive mentions, and there is a marked skew in the distribution of mentions (see below). Evans and Loach found that where they were mentioned, then articles from journals that had a higher impact factor also had a higher average number of mentions. This correlation suggested a coincidence between citation and mention behaviour.

Paul Wouters' team (CWTS, University of Leiden) analysed counts of mentions linked to individual articles in each journal. His team compared the specific number of mentions to an article with Thomson Reuters normalised citation index for that article. The normalised citation index takes account of the fact that citation counts rise over time at a discipline-specific rate.[8]

CWTS found that articles with a higher number of mentions did not necessarily have a higher normalised citation index. While there was an indicative trend between citations and mentions, there was not a sufficient correlation to provide any predictive value. The lack of a significant correlation suggested that the citation and mention behaviours were referencing different aspects of a paper's significance.

The two studies provide an apparent conundrum, which is the stimulus for this project. The conundrum may point to an important distinction. Frequently mentioned articles come from higher citation impact journals. To be published in a high impact journal is itself a mark of distinction since there is a high level of competition among contributors and a strong editorial and refereeing filter. But these frequently mentioned papers are not necessarily the most frequently cited in those journals.

Thus the conundrum leads to the hypothesis that if a paper in a well-recognised journal receives a high level of attention (many mentions) yet relatively few citations then that may suggest that the merit recognised by editors and reviewers and then by readers comes from content that goes beyond academic impact.

[7] The distribution of mentions across articles is highly skewed. This, and the place of the 'average', is discussed in detail below.

[8] Costas, R., Zahedi, Z., & Wouters, P. (2014). Do altmetrics correlate with citations? Extensive comparison of altmetric indicators with citations from a multidisciplinary perspective. *arXiv preprint arXiv:1401.4321*.

Hypotheses about mentions

What is likely to attract a high level of attention? And why does the kind of attention – mentions, but not always citations – focus on these papers?

It is important to recognise the multiple motivations for 'mentions'.[9] Mentions are a different referencing structure to that of the academic citation associated with the web of links between journal articles. There are no gatekeepers to replace editors and referees. There is no limitation on the numbers of mentions that can be made to different objects. So there are no filters and few constraints. Nonetheless, there are some social structures which mean that wholly uninformative or perverse referencing is likely to wither from lack of attention.

The motivations for mentions may arise from both serious professional or academic intent and from interest that follows social routes, which may still be wholly serious or may simply highlight the unexpected or bizarre - for which academic publication has always offered targets. The consequence is that there may be no single explanation for an article's count of mentions: an article can be both ground-breaking, of deep policy significance and of widespread public interest.

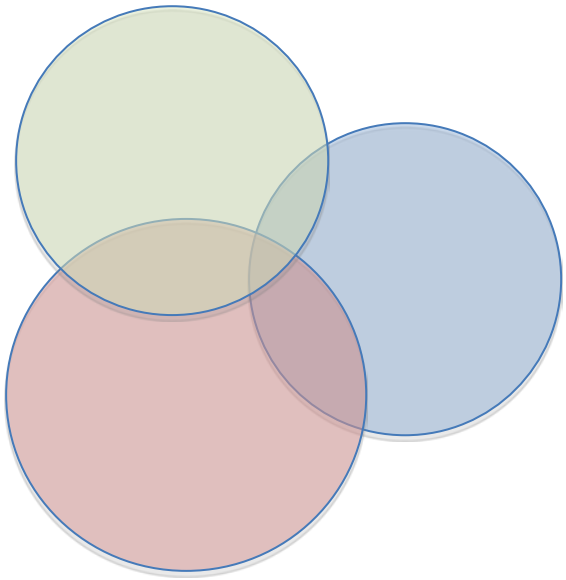
The challenge is to discern patterns that reflect concentrations of particular kinds of motivation, hence sources of interest. It may be that it is only when more data have accumulated that the proper separation of these 'signals' will be feasible, so present analyses must be treated as essentially speculative and the outcomes as provisional. While accepting this constraint, two experimental hypotheses that address innovation and the dissemination of research outcomes, in related but distinct contexts, have emerged from preliminary analyses. Both point towards new 'communities' using knowledge dissemination.

1. Practical and professional impact. A mechanism that enables rapid and accessible communication of innovative research outcomes relevant to a '*community of practice*' in the health sector would also be valuable to other research users and managers. Some papers may contain information of particular significance partly to further research (which will lead to their later citation) but of equal or even greater significance to professional practice (which would be reflected in mentions). The problem of translation from research into practice is significant. Practitioners do not always have the opportunity to scan current literature.

2. Stakeholder impact. Patients, carers and charity supporters of disease groups represent a '*community of interest*'. It is one that is more likely to be looking at, able to understand and then to wish to communicate outcomes in regard to research publications containing information about new treatments for critical conditions than would be true of the public generally. Unlike academics, they are not part of the citation network but they can use a social media network. Furthermore, if there are experts at the interface to link the research and stakeholder groups then this becomes a major route to wider knowledge dissemination and empowerment.

[9] Haustein, S., Peters, I., Sugimoto, C., Thelwall, M. and Larivière, V. (2014). Tweeting biomedicine: an analysis of tweets and citations in the biomedical literature. Journal of the Association for Information Science and Technology, 65, 656-669.

Professional practice – mentioning papers of significance for implementation



Public interest – mentioning papers of significance for health

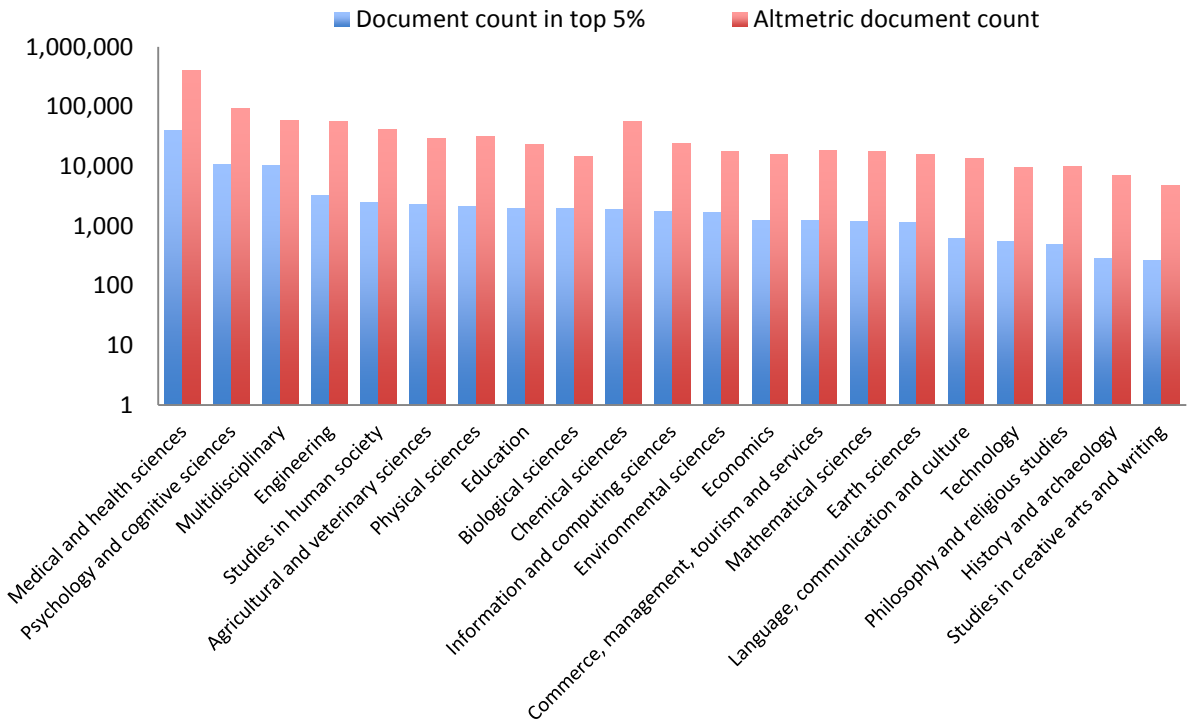
A diversity of other motivations

The objective of the work described here is to test these hypotheses in order to assess the extent to which mentions may be decoded to acquire signals of innovative outcomes.

Hypotheses about frequently mentioned papers

The research papers that attract Altmetric indexed mentions are not spread evenly among academic disciplines. They are clustered in areas relating to health and medicine. A similar concentration by main field is observed for journal documents indexed by Elsevier (*Scopus*) and Thomson Reuters (*Web of Science*™). The clustering of Altmetric data is, however, even more concentrated than that of the underlying literature.

Figure 1. Count (note: log scale) by field of research of documents mentioned recently (last 12 months) in Altmetric data collections. Medical and health sciences are the fields with both the greatest number of documents with any mentions and the largest share of documents among the 5% most frequently-mentioned.



The relative concentration of mentioned papers and the overall spread of mentions is reflected in an analysis of the distribution of mentions by paper and by field for the past 12 months (Figure 1). The analysis uses the Fields of Research (FoR) adopted by the Australian Research Council (ARC). The advantage of the ARC FoR journal categories, compared to other categorical systems for research papers, is that they relate well to conventional concepts of major research disciplines. They are also hierarchical, so we can identify high level fields (e.g. Chemical sciences) and then drill down to the nested minor sub-categories (e.g. Organic chemistry).

FoRs are inclusive: documents may be assigned to multiple categories. Where this occurs in this analysis then each assignment counts fully: no fractional counting is applied.

Two statistics have been calculated for each major and minor FoR. First, for quantity, a total count of mentioned papers: the count of documents for each FoR that occur among the Altmetric indexed documents. Second, for quality, a count of highly-mentioned documents: the count of documents in each FoR that scored in the most frequently-mentioned 5% of all papers with at least one mention in the last twelve months.

The FoR with the greatest number of mentioned documents is Medical and health sciences. This is also the category with the greatest number of documents among the top 5%. These two indices are generally closely correlated in these data. This is not so for Chemical sciences for which there are many mentioned documents but only a small share are frequently mentioned.

Research communities vary in size, of course. There are more researchers working and publishing in biomedical sciences than in physical chemistry. Biomedical research tends to lead towards shorter and more frequent publications than in other sciences. Engineers publish relatively more in conference proceedings than do scientists. So the underlying volume of clinical and biomedical research may include as much as 40% of total G7 publications in commercial journal publication databases.

Nonetheless, even given this relative disparity in indexed output, the social media point more towards biomedical and clinical sciences than to other science. They also point more towards social science research because ARC FoR 'Studies in Human society', which intersects with health research, has a relatively large number of mentioned papers. Furthermore, as we spell out later, within the biomedical area they tend to point more towards clinical medical papers than towards basic biomedical research such as genetics and molecular biology.

Data sources for this study

Altmetric data on media mentions

Social and news media mentions of articles and other document types found in research journals are tracked by Altmetric. Up to July 2014, Altmetric had acquired and collated mentions pointing towards at least 2,313,042 such scholarly documents.

The majority of the mentions are tweets. In just the last 12 months, over 4 million tweets have been logged, pointing towards more than 900,000 articles. The most frequently mentioned article received tweets from over 9,000 unique accounts.

Other sources frequently mentioning research literature include social media sites (such as Facebook and, more recently, the popular Chinese microblogging site Sina Weibo). Also tracked are mainstream media sources, blog posts and policy documents.

Table 1. Count by media source of mentions to research documents collected and indexed by Altmetric over the period August 2013 - July 2014

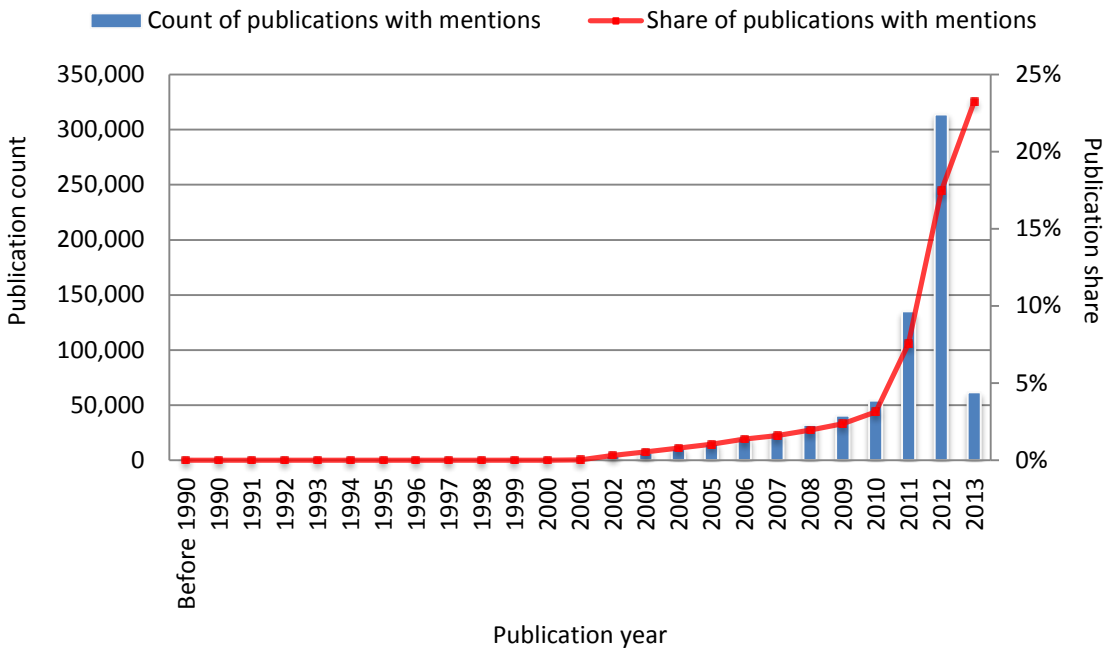
Source	Count	Source	Count
Twitter	4,405,086	Faculty of 1000	11,304
Facebook	253,992	Sina Weibo	9,847
News media	240,684	Video	8,126
Scientific blogs	132,875	Peer review	8,063
Googleplus	86,964	Policy documents	3,067
Reddit	15,053		

Altmetric only indexes research documents if and when they appear in one of the tracked sources, such as when someone tweets a link to an article. There are, however, many documents published in academic journals that receive no mentions from any tracked source. A comparison, by the CWTS team at the University of Leiden, of the numbers of mentioned documents to the total count of publications tracked in a leading index of scholarly articles shows that the attention tracked by Altmetric is pointing at a growing share of scholarly content in recent years, though this is obviously from a base level of older, scarcely mentioned documents in the period prior to online social media.

The trajectory of the trend described by CWTS, and their data matching to documents indexed in Thomson Reuters *Web of Science*™, reflects a rapid growth in the volume of mentions since 2009. The share of published work that is mentioned at least once has risen from less than one paper in twenty to almost one quarter of the total published output in early 2013 (Figure 2). That trend seems set to continue.

Figure 2. The rising numbers of research publications indexed in Thomson Reuters *Web of Science*™ that are mentioned at least once in Altmetric data. The Thomson Reuters database has expanded over the period but the share of indexed documents that are mentioned has grown faster, to about

one quarter. (Data and analysis: CWTS, University of Leiden; data for 2013 incomplete at time of analysis).



In the case of Twitter, demographic data are available on individual users. This provides a way of mapping the source of mentions geographically. An analysis by country of Twitter users' locations for data collated over the last 12 months confirms that while users tweeting information about research publications are widely distributed, the USA and the UK stand out as large contributors to these data as they also do to global publication output.

Figure 3. The global distribution of Twitter mentions of identifiable research publications during August 2013 through July 2014. Darker colour indicates more 'research' users (log scale of colour intensity) and actual numbers are given for named countries. The USA, Australia and parts of Latin America are very active. Data on total Twitter activity are not comparable.

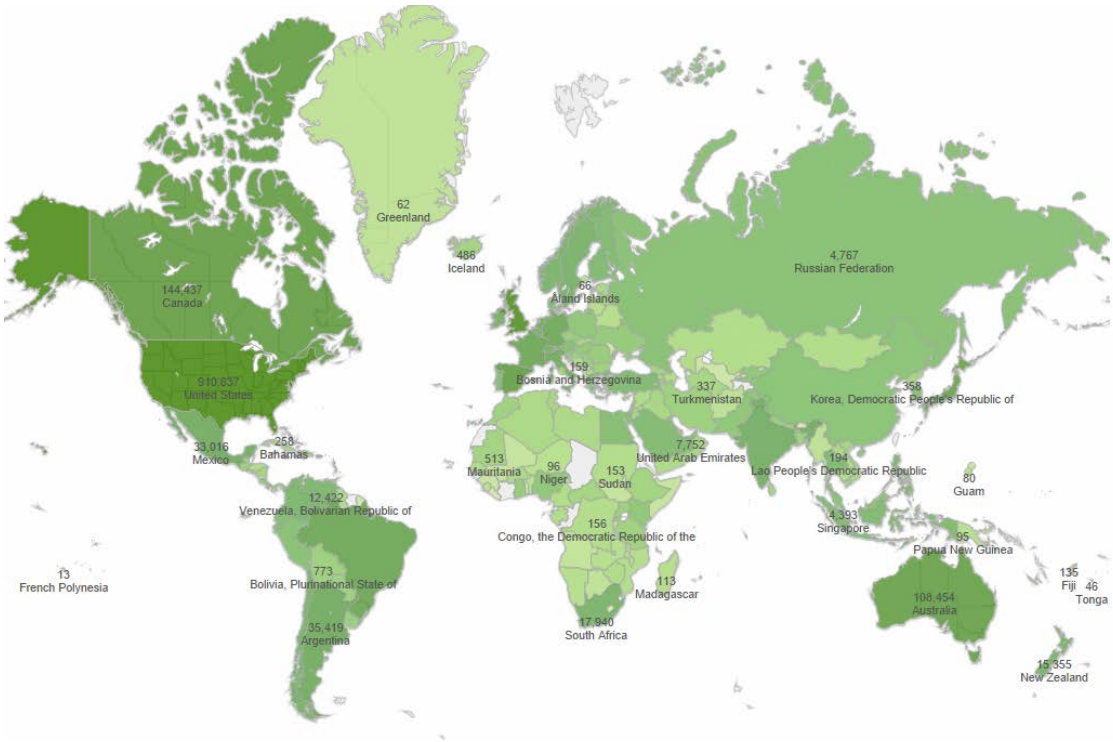
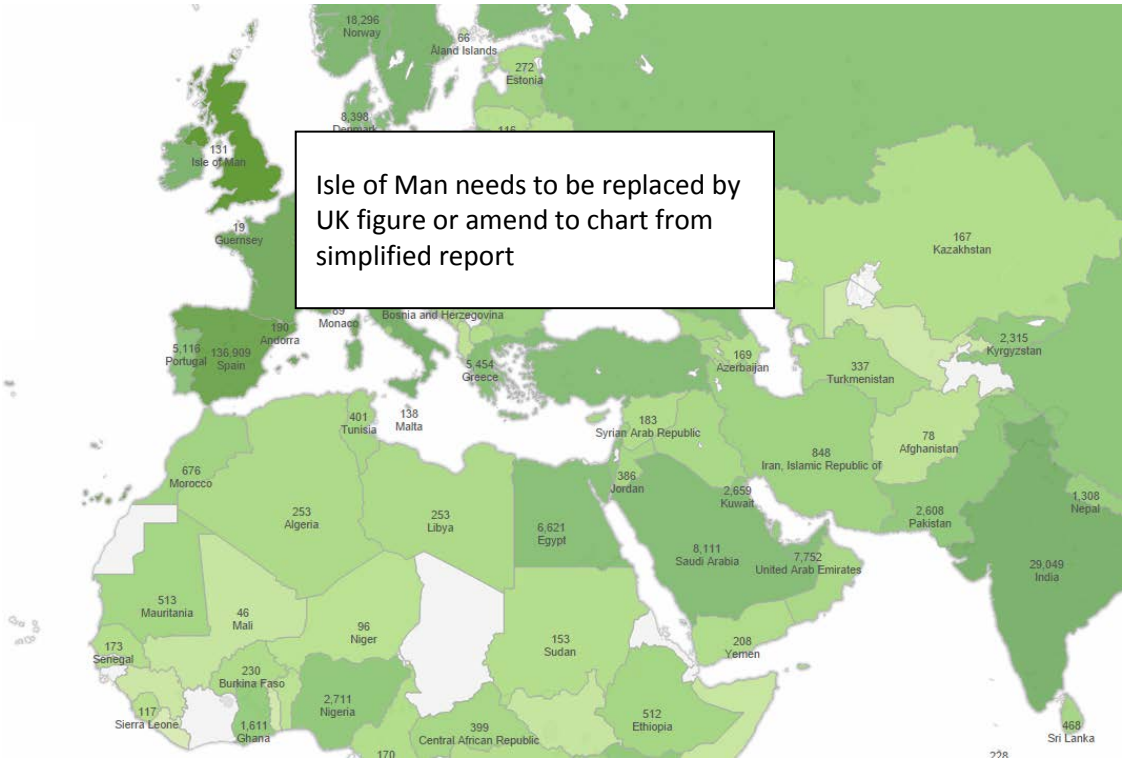


Figure 4. The European-African distribution of Twitter mentions of identifiable research publications during August 2013 through July 2014. Darker colour indicates more users (log scale of intensity) and actual numbers are given for named countries. Western Europe is a concentration of activity. By contrast, outside Egypt, there is a low level of social media referencing of research output in Africa.



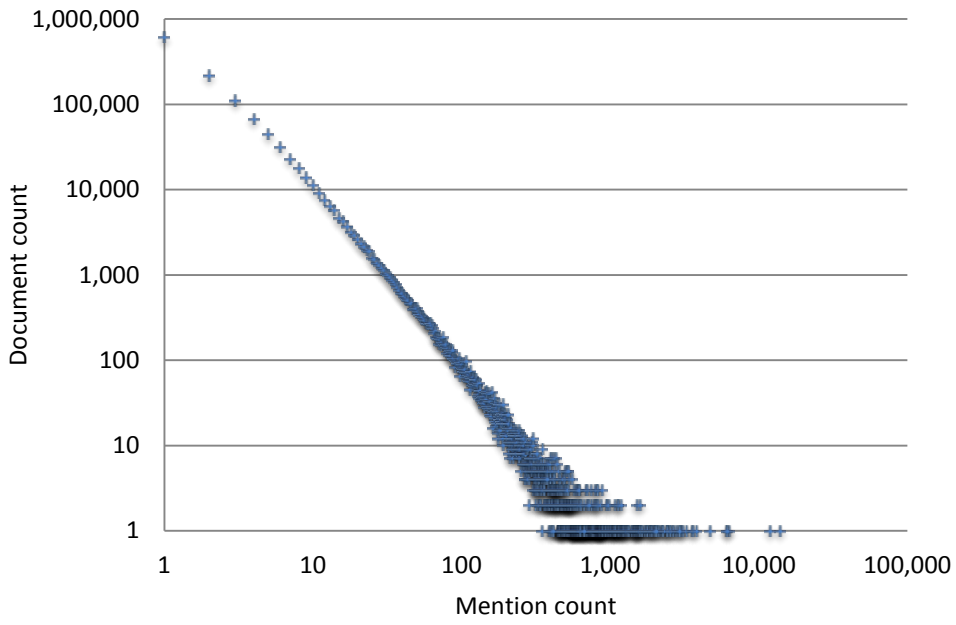
Linking mentioned papers to disease categories

This report has a particular focus on research publications in clinical medicine and health, where there is a concentration of social media mentions of such outputs. This report analyses documents identified in the Altmetric-indexed records that can be linked to complete bibliographic records in the MEDLINE®/PubMED® database. This linkage enables the use of a wide range of information about each publication, such as the research content and objectives identified in the article's title and summary abstract. The database also aggregates articles and journals by subject categories.

Altmetric has indexed over 2 million research documents, and the database is rapidly expanding. Of these, 1,234,681 could be linked to bibliographic references in the Medline database in early 2014, which is a higher share than generally reported because of a medical focus in the overall spread of mentions. The Medline database records also provide subject tags (Medical Subject Headings, or MeSH terms) that describe the content of the indexed items. There are 798,099 distinct bibliographic references in the Altmetric-linked data that have associated MeSH terms and from these 10,146,428 MeSH terms (an average of 12.7 MeSH terms per document) can be extracted to describe the content of the indexed items. Not all of these terms are disease specific, as we note in later analyses.

How are mentions distributed across documents? The mention distribution is highly skewed. For the set of 1,234,681 documents indexed by Altmetric and matched to Medline, it is apparent that a small proportion of documents receive a large proportion of mentions (Figure 5).

Figure 5. The numbers of Medline documents with 1 or more Altmetric mentions.



We cannot authoritatively say how many research documents have not been mentioned, because this would require some more detailed work related to different commercial databases and the varying assignment of document type.

As noted earlier, the skewed distribution of mentions per document is a general property across the entire Altmetric dataset. A similar skew is a property of citation distributions as well, but the distribution of mentions is in fact more skewed than that of citations.

This extreme skew affects any choice of analysis, the appearance of any index derived from the analysis and the interpretation that might then be applied. There are multiple sources of motivation to mention, and this introduces 'noise' amongst information 'signals' in the data. To attempt to filter out some of this 'noise', it has proved necessary for some analyses in this report to reduce the dataset to the research documents with relatively high (e.g. above average) counts of mentions.

Hypothesis 1 – 'mentions' indicate impact for research users

The first hypothesis derived from the observed patterns of mentions and citations to journal papers is that mentions are complementing academic citation by indicating papers that contain information of particular significance perhaps to their community of practice or for other innovative applications (as well as possibly to further research, which will lead to their later citation).

The basis for this hypothesis is that frequently-mentioned papers:

- tend to have been published in journals of high citation impact;
- are not necessarily frequently cited, though they may be;
- are more likely, in biomedical research, to be in clinical and heath research categories than in basic biomedical research categories.

Why is this useful?

The problem of translation from research into practice is significant. Practitioners do not always have the opportunity to scan current literature. A mechanism that enables rapid and accessible communication of innovative research outcomes relevant to their practice would therefore be valuable.

If social media provide that mechanism, and if the frequency of mentions is an early guide to research outcomes that are likely to have significant value to innovation in practice or in processes and products then this also provides an informative external reference for research and development managers and policy-makers.

How can we test the hypothesis?

To test the hypothesis, papers need to be categorised in terms of the type of impact they might have. This categorisation needs to be independent of the information about the frequency of mentions.

A journal publication bears no specific statement from author or editor that refers to its likely relevance or impact, though practice is changing in this regard (see below). We might assume, however, that experience in a field allows the expert to develop a mental template of research that carries significance for them. In a study for the UK Economic & Social Research Council[10], we found that experts did indeed use experiential criteria that allowed them to make a broad, initial evaluation of grant proposals, manuscripts or research groups. The idea that such quality criteria might be extended to consider likely impacts is therefore reasonable.

We therefore interviewed individuals with expert backgrounds as researchers, research managers, research funders and research evaluators. As the social media data are concentrated particularly in the biomedical area, most of the experts were also drawn from those fields.

Input from key informants

The hypothesis is that mentions of research papers in social media indicate outcomes of professional, practical or translational value. Papers that benefit professional practice might not always also convey exceptional academic (citation) impact. This would be in accord with the observed mention/citation patterns while such papers might be overlooked in conventional evaluation.

[10] Evidence Ltd. (2004). Bibliometrics for the social sciences. http://www.esrc.ac.uk/research/evaluation-impact/research-evaluation/bibliometrics.aspx

To test this hypothesis we need independent characteristics to allow us to categorise papers on the basis of their non-academic impact. We can then test the papers with relatively more mentions have these characteristics and whether this categorisation fits with the observed mention/citation pattern. Such characteristics might be found in meta-data associated with the publication record and, if so, they should be recognisable to professionals in that discipline. However, if informed experts judge that they are only able to identify the diverse merits of a paper after expert reading of the full text then a testable categorisation cannot yet be made.

In order to establish a starting point for our analysis we interviewed a group of relevant informants to draw on their experienced, professional view of the characteristics of papers that have professional influence, which might refer to particular journals, the style of the paper, keywords or key phrases in abstracts or introductory text.

In each case we asked the informants to respond in the context of their own expertise rather than anticipating any more general response. We accepted that they might judge that no consistent identification pathway was feasible and we asked them to be clear about this. We also asked about their use of research literature.

The topics we sought to cover were:

- Can research publications be separated into those of higher academic impact and those of greater professional impact but less academic impact? Or do some papers have high impact across many spheres?
- Do you think that your colleagues, or groups with whom you work, would be likely to recognise distinct bodies of work of academic versus professional significance?
- Do some journals publish papers with more academic relevance while others publish professional papers? Are there professional and academic readerships?
- Would you direct a paper that signalled an important development for professional practice to a particular journal that differed from the target for more specifically academic research?
- Are there signals in the title, keywords or abstract that convey significance for academic or for professional practice? Are some text-phrases or structures associated more with academic research and others more with clinical and professional practice?

Information about the interviewees is given in Annex A.

- Two principal topics suggested that this line of enquiry was likely to be frustrated.
- Other topics threw light on researcher behaviour.
- A critical outcome identified an alternative hypothesis, suggesting social media as a route to research-referencing by and for non-researchers.

Impact-type may be assorted across journals

A common point made by all respondents was that experienced authors generally direct papers towards a specific outlet they have found to be appropriate to the content, including its significance for a particular audience. On the whole, the objective would be to ensure publication in a highly regarded journal within their field. Researchers would select appropriate alternatives where they recognised that the outcome of a piece of work was likely to have impact other than through its value as innovative, blue-skies research discovery.

> "To influence other scientists, I would publish in journals in my expert domain. But to influence the system by drawing attention to the research then I would aim for a practitioner journal. This might be the BMJ (British Medical Journal) or it could be a non-WoS [NOTE: Thomson Reuters *Web of Science*™] journal. If the work is related to engineering then distinguishing between research and practitioner journals is much greyer."

> "[I] recognise a distinction between professional audiences for academic papers and a social constituency that requires non-academic communications."

The consequence of this professional approach would be to tend to cluster papers of academic impact, professional impact or practical/methodological impact differentially into particular outlets.

- *For expert informants, the proxy indicator of literature that has relatively greater academic or professional impact comes from the journal, not from characteristics of individual papers. This argues against the idea that significant outcomes with different kinds of impact might be found in the same journal sufficiently often to lead to the observed patterns of social media attention.*

Signals of specific impact are hard to discern

In general, informants were unable to identify particular features in the existing metadata of papers that would allow the *a priori* identification of those that had academic or other specific impact.

While research papers may often have more than one kind of impact, this has in the past less often been signalled by authors or perceived overtly by readers. There has been at least one study that sought to classify medical research output as 'basic' or 'clinical'.[11] This study started from the recognition that papers reporting basic research tended to be cited more often than those reporting applied work and clinical observations. One informant with whom we discussed this told us that he believed the method developed to make the basic/clinical classification proved of limited success and required much manual (and hence subjective) intervention.

Another informant referred to research in which he had been involved, which sought to identify citation types as a way of categorising significant health outcomes. Again, significant problems were encountered in developing a typology.

The analysis of reference lists was proposed as another source of data:

> "… a key difference between basic research and clinical trials would be the age of the literature on which the papers drew. The age profile of the references in a paper could provide a clue to the nature of the paper. Basic research is current, drawing on recent research with a quicker turnaround. Papers with practical implications will draw on a longer slice of literature … more considered and reflective."

Another approach would be via the mentions rather than the paper:

> "… attention can be short lived or demonstrate sustained interest … [you should] consider clustering papers into these categories as an area worthy of investigation."

However, this necessarily compromised any analysis since the reason for attention could only be determined after identification.

It was noted that while individual authors might have in mind an ideal a professional target sector or a community of practice, in practice there was likely to be a more diverse audience in which there were groups with different interests who might signal or communicate research information from different motivations and in different ways.

This does not mean, of course, that professional or practical implications are not already noted covertly, even subliminally. This could lead to the use of social media to signal such content.

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[11] Lewison, G. and Paraje, G. (2004). The classification of biomedical journals by research level. Scientometrics 60, 145-157.

> "Research that helps or influences the profession, or research with significant health outcomes, is likely to be disseminated through less formal, non-academic roots. Is that now Twitter?"

Such research may then be echoed by citation where the impact is academic but not where it arises elsewhere.

- *There is a lack of consistent characteristics that can be identified by informed experts reading papers with academic and professional impact. This argues against the practicality of a priori identifying journal articles with these different kinds of impact and then being able objectively to analyse the attention that they attract in social media.*

Mediating research into practice remains a challenge

Irrespective of whether research outcomes are directed towards select journals with particular audiences, informants generally agreed that the mediation – or translation – of research outcomes into advice to practitioners remains a challenge.

> "… social media might contain a substantial amount of information about the process by which research feeds into practice ... social media are a potentially useful complementary route to conventional academic practice …"

Attention was drawn to a shift in practice regarding the presentation of a paper's significance or value and the ways in which that can be conveyed to different audiences. The impact agenda is changing editorial approaches.

- Ergonomics (Taylor & Francis) is a journal at the interface between an academic field and a large and diverse practitioner community with social and economic impact. It has established a practice of attaching a practitioner-orientated 'statement of relevance' after each formal academic abstract.
- BMJ (The British Medical Journal, BMJ Publishing Group) now specifies that the abstract should include a statement on 'what this paper adds' and is making other changes "to tackle the power imbalance between patients and the 'medical industrial complex.' "[12]

It is evident that a growing stakeholder network is not only conscious of but also reacting to the multiple facets and values of research impact and aware that these can usefully be identified and signalled. So, if editors do indeed see multiple routes to impact in the same papers, then that suggests a library of similar value that has not been adequately marked and tapped in the past.

One informant asked about social media in the context of conference proceedings. He pointed out that a conference was a forum in which researchers, research users and practitioners came together and shared information directly. Conference proceedings tended to have relatively few citations: did they have fewer mentions than journal articles? There was no comprehensive reference database to test this. But actually, the use of social media within conference forums might be an informative guide to papers that produced significant reactions.

- *There has been no simple route for research users to communicate value but social media may fill this gap.*

[12] BMJ. (2014). Towards the patient revolution. *BMJ* 348:g1209. doi: http://dx.doi.org/10.1136/bmj.g1209 (Published 29 January 2014).

Researcher behaviour affects outcomes and is evolving

Informants suggested that the reasons why researchers might mention a paper were even more diverse than reasons why they would cite a paper. One informant had been involved in a workshop with ten authors to discuss social media experience.

> "Some scientists are better at "promoting" their work than others - one seemed to think she was good at self-promoting via social-media and could see that others were less so ... [tweets] may say more about the person tweeting than content and worth."

There were concerns that social media may be more readily used to highlight outcomes that reinforce current practice, particularly if this is something that the person messaging believes. This confirmatory bias has been noted as an aspect of other referencing[13], including citations.

> "… people will tweet things that they believe to be true and which confirm that they are already good practitioners. They are less likely to communicate information that tends to contradict what they already practice."

The likelihood that social media would tend selectively to draw on research outcomes, perhaps to cherry-pick those that reinforced particular practice, was echoed elsewhere:

> "… there is evidence of antagonism towards evidence-based research ... there is a strong residual tendency in the NHS towards practice based on gut feeling."

Another informant suggested that social media would be used to indicate an individual's awareness of particular kinds of research

> [There is a] "risk of tweeting around vogue topics. Analysis by sub discipline would be important to identify this. For example, research associated with cancer and with children could receive a great deal of attention whereas research associated with mental health and with the elderly would get less … this would cut across other factors around research results."

One informant suggested a possible change in behaviour:

> "How would researchers describe differences between impact typology for basic and applied research? 'Basic' researchers would say that their work had application but the application was further off, it was too early to tell what the impact might be.
>
> "(With changing policy) ... it will be difficult to get researchers to identify how their papers might not contain information about application and professional impact ... if there is a political impetus to prioritise impact then authors would likely include information to point in this direction."

- *Researcher behaviour in regard to the use of social media has multiple motivations and their 'impact awareness' is evolving. There may be informative signals in media attention to research papers but they may be difficult to deconstruct until more data are available.*

[13] Nickerson, R. S. (1998). Confirmation bias: a ubiquitous phenomenon in many guises. Review of General Psychology, 2, 175-220. MacCoun, R. J. (1998). Biases in the interpretation and use of research results. Annual Review of Psychology, 49, 259-287

Social media includes referencing by non-researchers

The identification of significant research outcomes via citations is a signalling system restricted (almost) entirely to researchers and principally to academic researchers. It is a codification of intellectual debts by those engaged in testing and generating knowledge.

This is not the case for social media, which provide an accessible route for rapid communication. Although there are no 'gate-keepers' such as journal editors and referees, there may be key communicators who provide facilitating channels and such individuals may be on the professional or the community side of the network.

> "Where a large advocate community exists, that includes self-taught experts who scan the literature looking for perceived positive and supportive research which they could then rapidly communicate through Twitter and other means."
>
> "… there may be communities of interest associated with disease areas ... there may be key people that span boundaries in networks of interest, curating content and passing this between networks."
>
> "… 'Champions' who can promote activity in a network … advocacy activity … encourage adoption of new practice (this could conflict with professional objectives) …"
>
> "… [I see] 'communicator' roles between the academic community and a wider constituency such as carers and patients ... would it be possible to use [mentions] to identify key communicators, build information about them and then use this to profile roles for good practice?"
>
> "… where a new drug is the only option for treatment – it's likely to gain more interest and score well on altmetric. Breakdown by disease could be insightful here."

These observations led to a discussion with several of our informants around a second hypothesis to explain the observed patterns of social media mentions and academic citations for research papers.

- *Not all stakeholders in research have a direct influence but they may have an acute interest. Social media enable them to signal that interest where they see research publications of significance.*

Analysis

In the absence of a set of 'expert' criteria to identify papers likely to have significant value or impact for practice, it was necessary to follow a more subjective route to explore characteristics for the more highly-cited literature and compare this with similar but less mentioned papers. This could not provide a conclusive test but it could draw attention to possible characteristics for further analytical investigation.

Visual scan of frequently mentioned articles

A sample of 'most mentioned' articles were accessed and read to establish whether they had any discernible common characteristics.

Many of them were reviews, either explicitly labelled as such or apparently filling that niche. It is recognised in bibliometrics that reviews tend to be cited more frequently than other journal articles

and for this reason they are often treated separately in citation analysis.[14] However, a further check showed both that many frequently mentioned articles could not be categorised as reviews and that many explicit reviews in the same journals were not frequently mentioned.

Thus, 'review' may be a characteristic that makes an item likely to be mentioned but it is not in itself a compelling feature in this context.

Sandwich comparisons

A good basis for comparative analysis is to use papers of the same age and related content. The simplest way of doing this is to compare a target or sample paper with the two articles that immediately precede and follow it, i.e. those that sandwich it in terms of pagination in the same journal issue.

This approach is a simplified and subjective parallel to a sign-test devised by Haustein et al.[15] In their test, each article was also compared with the two articles published immediately before and after it. They were tracking citation/mention comparisons and thus needed to use articles of approximately the same age, similarly exposed to the same citation delay and usage uptake biases. Our analysis merely required categorization.

Two journals with a relatively high concentration of frequently mentioned articles (Anesthesia and Circulation) were selected for intensive sandwich comparisons. The twenty most frequently mentioned articles were identified and compared with the articles 'either side' in page sequence.

Again, no discernible characteristics were identified that would either consistently differentiate the highly-mentioned articles from their neighbours or provide a common association for the mentioned articles.

Document type analysis

The likelihood that mentions are generated by specific research interest or by other factors may be reflected in the distribution of mentions across document types.

Averages are not necessarily informative as to the overall distribution where data are very skewed, as is the case for mentions. We calculated medians and looked at the median count of mentions for document types, but this is affected by the very large number of papers with one or few mentions. We truncated the dataset to those papers that had at least 10 mentions and looked at the count of documents within this relatively frequently-mentioned group as an arbitrary but transparent interim indicator for this exploratory work.

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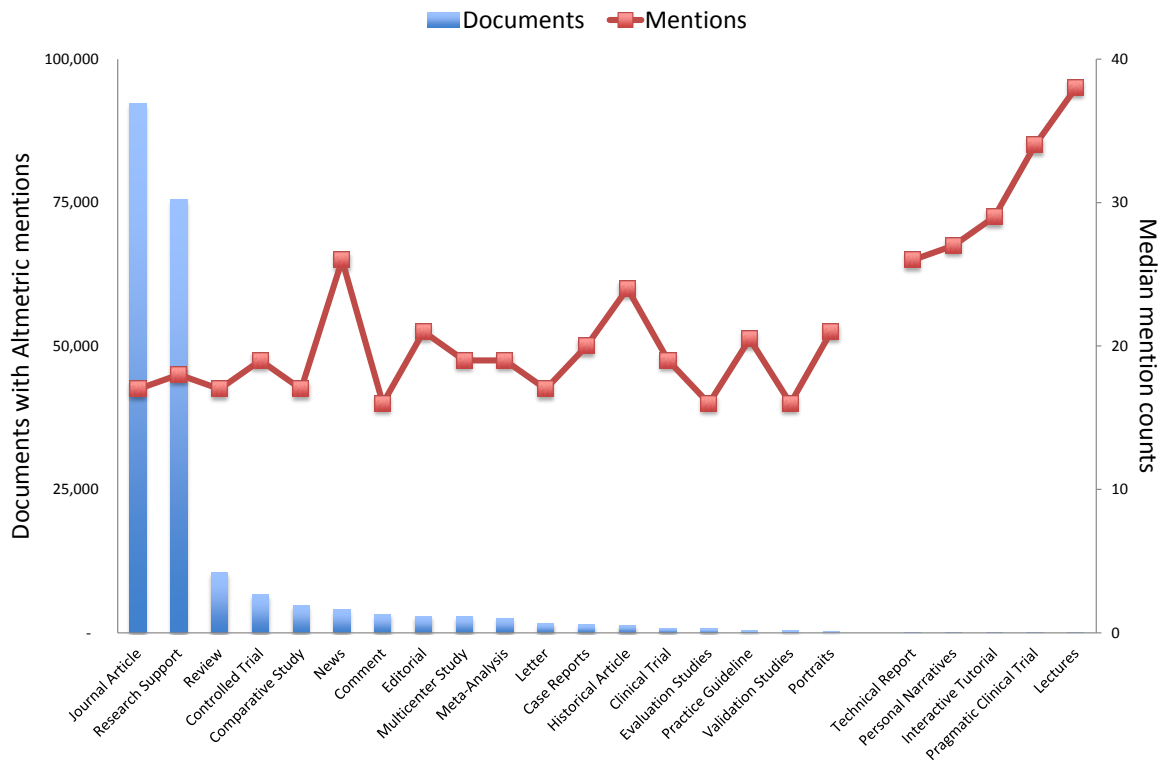
[14] Garfield, E. (1994). *The Thomson Reuters Impact Factor*. Thomson Reuters. Bornmann, L. and Daniel, H-D. (2008). What do citation counts measure? A review of studies on citing behavior. Journal of Documentation, 64, 45-48

[15] Thelwall, M., Haustein, S., Larivière, V. and Sugimoto, C. R. (2013). Do Altmetrics Work? Twitter and Ten Other Social Web Services. PLoS ONE 8(5): e64841. doi: 10.1371/journal.pone.0064841

Figure 6. The distribution of Medline document types for research documents indexed by Altmetric and receiving at least 10 mentions. Most document types are never mentioned and these are filterd out to reduce 'noise'. In later analyses a higher threshold is applied (e.g. top 10% most mentioned) to focus on Journal Articles.



Documents classified as 'pragmatic' clinical trials, technical reports and lectures were mentioned relatively frequently if they received any mentions, so they score highly in analyses of average or 'median mention count'. However, these types were also rare in the overall Altmetric-Medline dataset: only very small numbers of such documents were mentioned at all. By contrast, the most common types of mentioned documents were journal articles or were about research support from various sources. Such document types (it is not entirely clear that every 'document' classified by Medline is in fact a research publication in a conventional sense) reflect quite different publication purposes from journal articles, so this confirms the diversity of motivations for mentioning a document.

The distribution reflects the complex dynamics of mentions. Many journal articles are mentioned, but some are only mentioned a few times. Few 'lectures' are mentioned but if mentioned at all then they tend to receive many mentions (this could be, for example, a student network). This increases the need for caution in interpreting mention profiles for any group of documents.

Conclusions

Expert opinion did not lead to any clear identification of the characteristics of a research publication that was more likely to carry economic, social or professional impact rather than academic impact. On balance, the view was that the latter publications might appear in different journals, possibly with different target readership. Within journals there was more likely to be similarity of author purpose as regards impact, so the differences seen in the CWTS and Imperial studies are not readily explicable in these terms.

Comparative analyses (visual scan and side-by-side comparison within journal context, and document type analysis) were no more illuminating in this context. However, the document-type analysis confirms an earlier view that there can be many motivations for mentioning a research-related document. It is true that lectures and lecture notes are not usually seen as original research publications, but in fact they are an important research output in some technical disciplines.

Overall, there is no clear view from a 'research side' approach as to why some articles in a journal may get mentioned frequently when others do not. That raises the possibility that an alternative perspective, from outside the academic arena, may provide more light.

Hypothesis 2 – 'mentions' provide a referencing medium outside academia

The second hypothesis derived from the observed patterns of mentions and citations to journal papers, and arising from discussions with research informants, is that social media can complement the academic route to referencing a research paper. They enable non-research stakeholders – such as patients and carers – to indicate papers that contain information of particular significance to the network of interest in which they are involved.

Why is this useful?

Social media offer a non-academic parallel to citations. Citations individually provide a route to acknowledge intellectual debts and collated citations point to work of significance because of its influence. But citations take time to accumulate and are a signifier primarily for those also involved in research. No parallel system of signifiers has been available to those other stakeholders who are interested in research and its outcomes but are not themselves publishing. Social media creates such an alternative, enabling rapid identification and dissemination of recognition for innovative research outcomes perceived as relevant to a particular disease or condition.

If mentions are driven to a significant extent by stakeholder networks associated with a particular disease then we should expect to see a correlation between the average number of mentions that a paper receives and the size of the associated community which might form the social network.

How can we test the hypothesis?

To test the hypothesis, the size of the communities associated with a particular disease need to be estimated. This figure can then be compared with statistics for the numbers of mentions for papers relevant to that disease area.

We cannot directly measure the size of these stakeholder groups so we need an appropriate proxy. For example, it might be possible to use information linked to the medical research charities. We might expect the number of people supporting charities, and therefore active in their interest around the disease, to be correlated with the amount of social media activity in the research area. In the case of cancer, there are many charities dealing with quite specific cancers so the link between particular research papers, social media mentions and the amount of research funding should be analysable. In fact, even calculating the numbers of people in that context is difficult, so a further proxy is required in the form of the total research support going to each disease area.

Categorising disease data

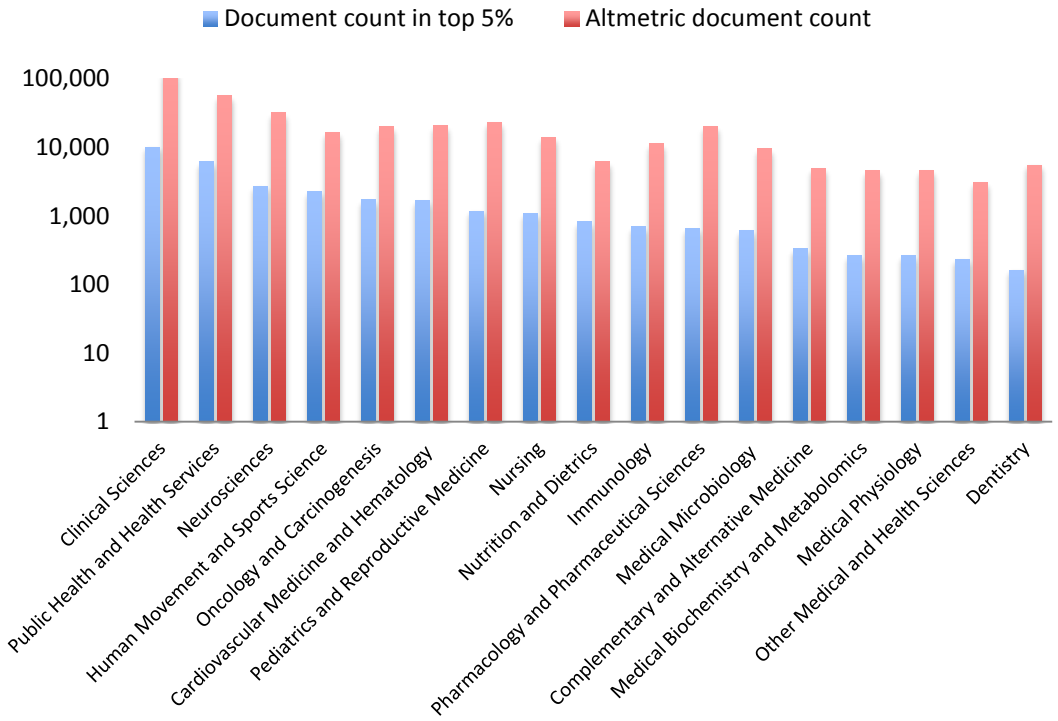
The hypothesis focuses on diseases, so data on publications and data on research funding need to be brought together via disease categories. Mapping data to categories is a non-trivial problem as most organisations are idiosyncratic in aggregating information around their particular objectives.

Research papers can be aggregated via the journal categories used for commercial databases such as Thomson Reuters *Web of Science*™ (254 categories) and Elsevier's *Scopus*. However, because these are journal categories they do not correspond very well to the typology required for this project. For example, extensive work in molecular biology and genetics is relevant to a particular disease but the journal category does not convey that information.

We analysed the 'medical' categorical spread in two ways. First, we drilled down into the more detailed FoR categories in the ARC system. The spread across sub-categories in Clinical and Health sciences reveals further variation when we compare the total number of mentioned documents with the numbers of documents among the overall 5% most frequently-mentioned. For example, Human movement/Sports has fewer total papers mentioned than Public health but it has more frequently-

mentioned papers. In other words, if such papers are mentioned they are more likely to be mentioned relatively often. This is also true of papers in Oncology and carcinogenesis.

Figure 7. Count (note: log scale on vertical axis) by minor research field within Clinical and health sciences of documents mentioned recently (last 12 months) in Altmetric data collections. Clinical sciences is the ARC Field of Research with both the greatest number of documents with any mentions and the largest share of documents among the 5% overall most frequently-mentioned. Recent data are used to cut the early years when mentions were accelerating.



Pharmacology and Dentistry are contrasting examples, of fields where there are relatively fewer frequently-mentioned papers compared to other fields with similar total mentioned documents.

There are several interpretations that might be applied to these patterns. On the one hand, this could indicate that a frequently-mentioned Dentistry paper is of particular significance because they are rare. On the other hand, the greater relative frequency of Oncology papers may suggest a higher level of overall attention to research in that area. The example of Pharmacology is difficult to interpret either way: there is a high count of mentioned papers but relatively few frequently-mentioned papers.

The ARC FoRs are not the only way in which the mentioned papers associated with medicine and health might sensibly be categorised. Biomedical publications can be assigned to topics individually via MeSH (Medical Subject Heading) terms created by the US National Library of Medicine and applied to over 5,000 journals in the MEDLINE®/PubMED® publication database. There are over 27,000 subject headings in the 2014 version and over 200,000 supplementary keywords. Each paper can be associated with multiple terms. This makes the system far more granular and flexible for

analytical purposes than does categorisation in commercial databases. It allows individual papers to be associated with more narrowly defined topics.

Of the total Altmetric research documents, there 439,456 that can be linked both to the Medline publication database and for which there is at least one associated MeSH disease term (many MeSH terms are not disease-specific). These terms are not exclusive and there are up to 20 per paper in this dataset, with an average of 2.02 MeSH disease specific terms (as compared to the larger number of general health terms) per Altmetric matched paper. For manageability, the detailed MeSH terms are grouped into a smaller number of high level categories. Each disease term can be mapped back to these higher-level branches of the MeSH system.

Where multiple disease terms exist for one document, that document - and its mentions – are counted fully towards each high level disease, with no fractional counting. The most common term (Pathological Conditions etc.) is not analytically informative as this is a generic term that is applied across many more specific disease areas.

Figure 8 summarises the data in terms of the total numbers of papers associated with each disease area. Figure 9 filters the same papers and shows the aggregate mention count for the most frequently-mentioned 10% and then just the top 1% of overall papers. This is a smaller, disease-specific data set to that described earlier in the report. We apply the 10% threshold here (rather than 5% in e.g. Figure 7) to increase the information we capture from the smaller sample. This provides a less discriminating filter between noise and signal in the analysis, however, so we then apply a draconian 1% to confirm the sense of the outcomes.

It is evident that oncology (as Neoplasms), neurosciences (nervous system diseases), cardiovascular diseases and nutrition are the most frequent either by total count or for aggregate count of mentions for each disease category among the overall most-frequently mentioned 10% and 1% of papers. In fact, across the 26 categories in Figures 8 and 9 there is a strong correlation. Disease categories with a large volume of mentioned papers tend to have a high aggregate mention count among the overall frequently-mentioned papers.

These are not independent indicators, of course. More mentioned papers will, on average, lead to more aggregate mentions; this would be expected to produce a similar ranking on average. However, we are also truncating the sample to look at only the most highly-mentioned papers. This then highlights categories with a disproportionate rank on one indicator compared to the other.

Three categories shift rank markedly compared to the rest (five places in each case). The disease categories with a higher position on the frequently-mentioned indicator are Virus diseases (up from 11th by paper count to 6th by mention count) and Wounds and injuries (up from 16th to 11th). The disease category which has a lower aggregate mention count considering its paper count is Digestive systems (down from 7th to 12th).

What this indicates is that when Virus and Wound papers are mentioned frequently then, compared to other papers, they often get an exceptionally high mention count. Digestive papers, on the other hand, appear to get rather lower peak mention counts.

Figure 8. Count of Altmetric mentioned documents by MeSH disease term.

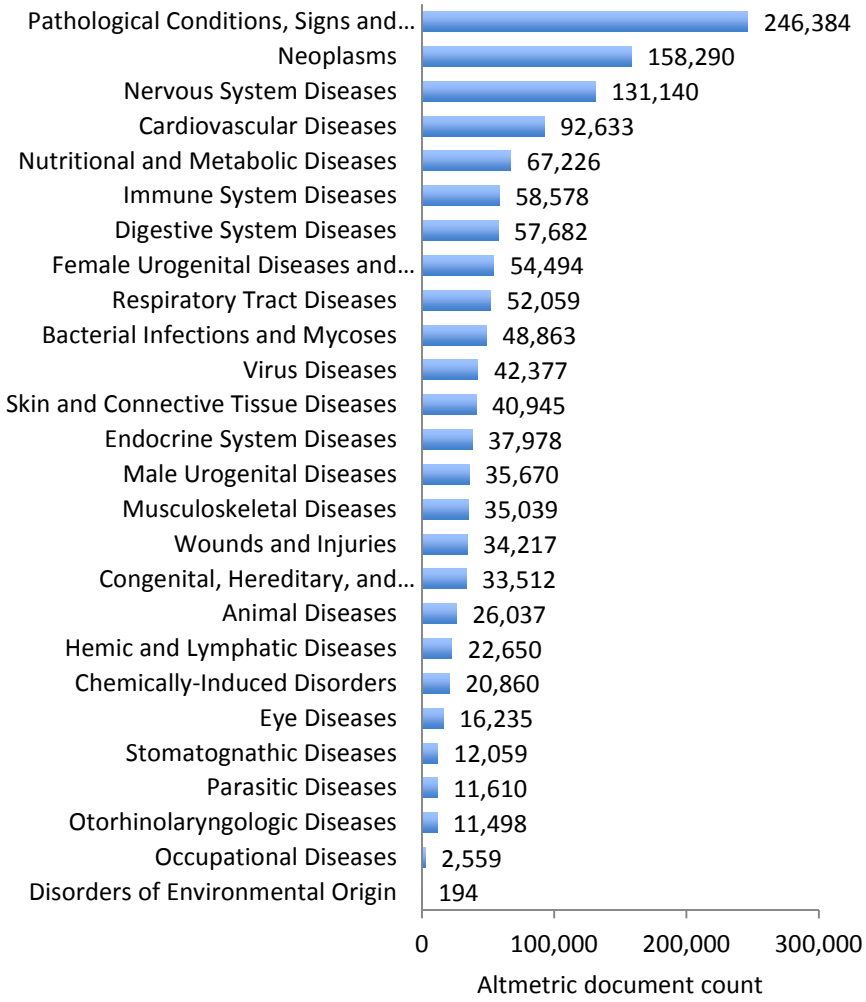
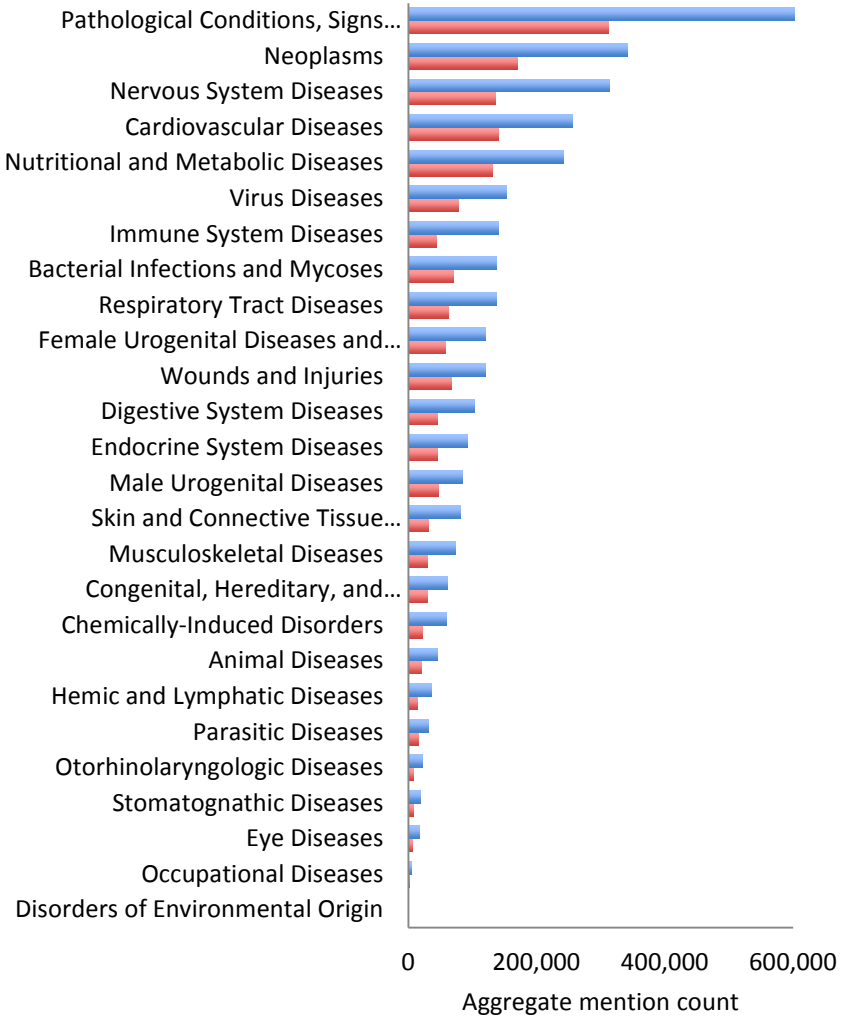


Figure 9. Aggregate mentions for most frequently-mentioned 10% (blue) and 1% (red) Altmetric indexed documents by MeSH disease term.



Categorising funding data

In this report, to create a comparison between research funding, as one indicator of disease attention, and Altmetric mentions of research papers, as another indicator, we have used one comprehensive source of UK data on charitable research funds. We do not have access at this time to any unified global data at disease level. It should be possible to extend the analysis to include other specific countries, such as the USA and use these as a test of the outcome in this report.[16]

Funding for biomedical research in the UK comes from many sources, including the Medical Research Council (MRC), but the MRC supports much fundamental research addressing many possible disease targets. More specific research funding comes through the Association of Medical Research Charities (AMRC).

An individual charity could have a well-defined disease-related mission but may then fulfil that mission through a portfolio of research routes. This is slightly problematic for our analysis. For example, a significant proportion of funding is associated with cancer. Grants for research associated with cancer are awarded by a diverse network of charities with specific disease targets, for example, in childhood cancers or in breast cancer, but also by Cancer Research UK, which has a very broad remit. This means that any analysis may require a broad approach, which is robust but unspecific, and a finer grained approach, which could be more specific but requires very careful data assignment.

The data categorisation used by AMRC for its classification of medical research funding does not follow the Medline MeSH terms as these would be overly detailed for funding purposes. Instead, the AMRC uses the Health Research Classification System (HRCS) to categorise charitable medical research. The HRCS is a standard classification approach for the analysis of health research portfolios, developed by the UK Cancer Research Campaign partners in 2004.[17]

Collated AMRC data from 29 medium and smaller sized member charities confirm that cancer receives about 25% of UK charitable medical research funding and that inflammatory & immune, musculoskeletal and neurological research each receive around 15%. The other 30% of funding is spread across a wide range of disease areas.[18]

The hypothesis is that well-funded areas equate to areas of significant public attention and that this would be reflected in attention to research outputs via social and other media. The AMRC data, grouped by HRCS category, therefore need to be mapped or linked to the Altmetric data, grouped by MeSH disease term. A map between HRCS and MeSH disease terms would then allow an analysis of the possible relationship between levels of charitable research spend and an indicator of Altmetric attention by disease area.

We drew on prior research category mapping used by *Evidence* Ltd and Thomson Reuters to create a reference between the two systems. There is, in practice, a reasonably close overt relationship since the two systems both rely on categorisation around major disease areas. A small number of categories in the MeSH system were condensed within HRCS categories but cross-checking with information on journal usage suggested these were uncontroversial. A validation check by

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[16] Funding for biomedical research in the USA comes from a number of state and charitable sources, including the National Institutes of Health (NIH) and the National Science Foundation (NSF). It would therefore be possible to extend the preliminary and UK-orientated test and see if it is supported by a view from this independent data perspective.

[17] http://www.hrcsonline.net/

[18] Figure 4 in: UK CRC. (2007). From donation to innovation: an analysis of health research funded by medium and small sized medical research charities. AMRC/CRC, London.

ÜberResearch GmbH (Cologne)[19] was incomplete at the time of reporting but should be used to inform any subsequent development.

Correlations with AMRC funding

We have two expectations to test. One is that papers are more likely to be mentioned (i.e. attract media attention) where there is substantial charitable research support (a proxy for recent public/donor attention). However, a counter-argument might be that more research support drives a greater volume of output which would reduce the likelihood that any but papers of high significance would receive attention.

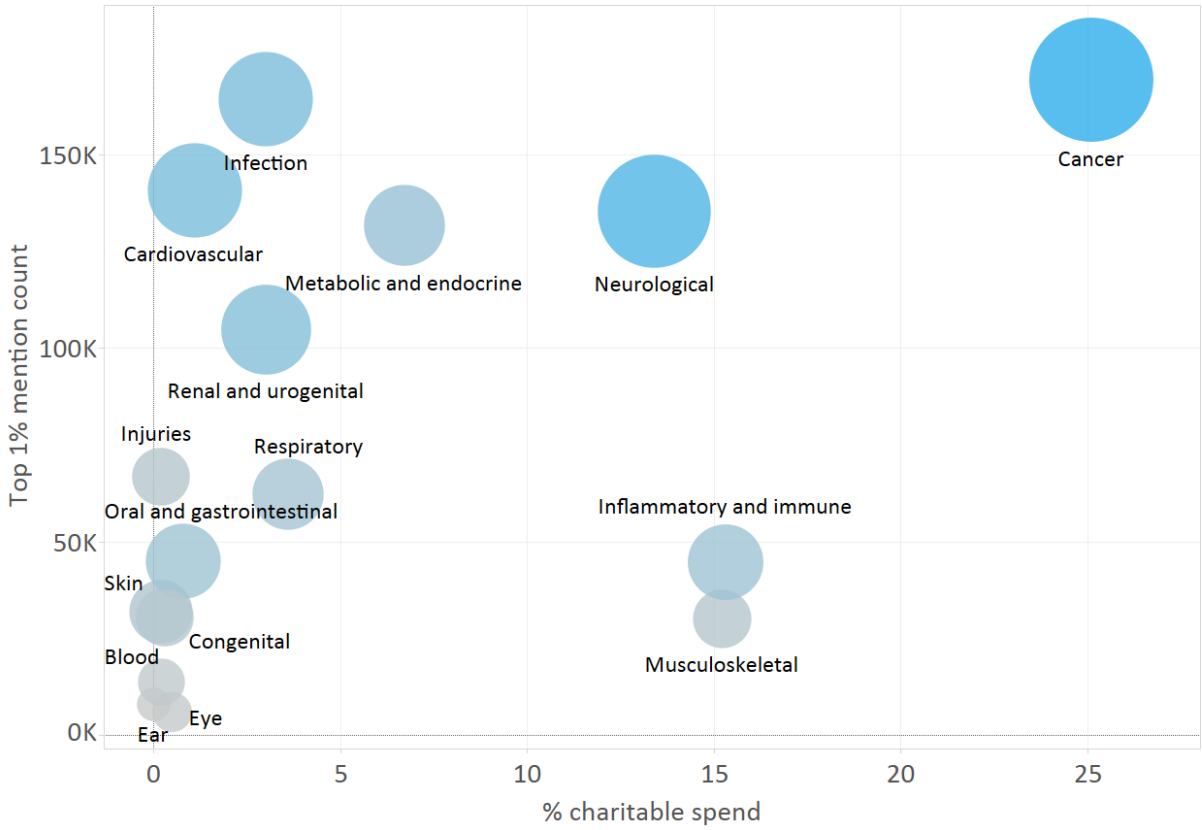
The second expectation is that papers that are mentioned will receive a higher total count, on average, where there is a high pre-existing level of interest. The available funding is related to the size of the fundraising group and its motivation and therefore serves as a proxy of the strength of interest.

The highly skewed nature of mentions amongst documents – with a few research papers mentioned very frequently while many are mentioned only a few times – is true not only across the overall set of Medline papers linked to Altmetric data but also in each specific disease area. This creates a problem for analysis, as noted earlier in this report, not least because where mentions are scarce it is possible that they are also driven by different motivation and provide clashing 'signals' of attention. There may be many documents of minor significance. Papers that are mentioned frequently are likely to have built up attention because of a more coherent source of significance.

To limit the data to those papers that are receiving more than transient attention, we reduced the data to include only the most frequently-mentioned 1% of disease-related papers. This cuts out the overwhelming effects of the many barely-mentioned documents. For each HRCS disease area, we then compared share of UK charitable research spend with the count of mentions for papers referring to that disease and among the most frequently-mentioned 1% of papers. It will immediately be obvious that we are comparing a regional proxy of community interest (funding) with a global proxy (mentions). It will be feasible to test the generality of this when additional data are available on US charitable research spend.

[19] UberResearch provides research funders with information tools based on natural language processing for automatic portfolio analysis, linking project and programme categories.

Figure 10. For HRCS disease areas, the relationship between that area's share of UK charitable research spend and the count of mentions for papers describing research on the disease that feature among the top 1% most mentioned in Altmetric data. Bubble size and colour depth reflect the number of Altmetric documents for that disease.



The picture captured in Figure 10 produces some challenging outcomes.

The position of Cancer and Neurological disease - compared to that of Blood, Skin and Respiratory diseases in this analysis - shows a positive relationship between charitable research spend and the relative attention given to frequently-mentioned papers. Higher peaks of attention are achieved by research papers associated with diseases tackled by charities with larger research funds. The correlation between mentions and spend is not quite significant (0.06>P>0.05).

Although there is a general trend, Cardiovascular disease actually receives much more attention in this analysis than would be expected given the apparently lower level of charitable research spend. By contrast, spend on Immune and Musculo-skeletal diseases is high but the level of media attention to research papers is low compared to, for example, Neurological diseases.

Discussion, conclusions, emergent issues

Media mentions are a valuable new tool for professional and societal networks to draw rapid and informal attention to accessible information about innovative research. They are complementary to publication and citation links, working in parallel but avoiding the hurdles and delays of conventional academic routes. However, we need wider recognition of the dividends and engagement with the use of social and news media. We need to diversify the serious attention given to research and innovation if such communication forms are to realise their potential benefits.

Media mentions can draw attention to innovation that is significant for both public and professional reasons. For example, a network of need and opportunity exists for stakeholder groups engaged with acute diseases for familial/social reasons. Our data show that there is an emerging correlation between charitable research spend and Altmetric mentions. This is already significant statistically – albeit at a low level – and it already raises challenging questions about diseases with high levels of attention but apparently lower levels of research support.

Methodologies for analysing 'mention data' need to progress to assist non-academic groups in maximising beneficial use. For example, it would be valuable to develop profiles of individual users. It is likely that key facilitators communicate research results between the academic and the non-professional but informed networks.[20] We anticipate that such key nodes in networks also exist in professional health/clinical contexts.

Nursing and health professionals are another group affected by research outcomes and innovations but they cannot access the medical researcher's citation route to indicate significance. Nor is the delay between reading, writing and publication helpful to their communication needs.

Rapidly growing data resources cannot yet be deconstructed sufficiently to confirm it statistically, but the relative frequency of mentions for review papers suggests that biomedical researchers and clinical and health professionals already use media mentions to draw attention to valuable and innovative outcomes, techniques and recommendations.

Both mentions and citations are used to communicate discoveries, but it may be misleading to draw too many comparisons because a supposed similarity can distract from the need to work towards individually optimal analytics and specific insights.

There is a relationship between the content of biomedical research papers and the frequency with which they are mentioned in Altmetric.com data, but no analysis can yet provide any definitive outcomes. The plurality of potential stimuli for mentions is a source of cross-cutting signals without the custom filters that make the information content easy to discern. Such filters are needed.

Recognising and describing communication roles and opportunities may enable their development in other networks since such roles reflect value and esteem when the real benefit of rapid and 'serious' communication is validated. That lack of current validation may explain low media use in Germany, and overcoming that generally may trigger much wider and constructive engagement with the possibilities that the media offer.

[20] A similar idea has been proposed by Stefanie Haustein in the context of astronomy, where there is again a significant non-professional network of interested individuals Haustein, S. and Larivière, V. (2014). Astrophysicists on Twitter and other social media metrics research. Harvard-Smithsonian Center for Astrophysics; February 7, 2014

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ANNEX A

Key informant interviews

Digital Science received funding from Nesta (formerly the UK National Endowment for Science, Technology and the Arts) to explore the potential use of alternative metrics as indicators of the economic, professional and social impact of research publications.

The starting hypothesis, from observation of the distribution of Altmetric 'mentions' of research journal articles, was that professional groups in the health/biomedical sector might use media networks to alert colleagues to research outcomes of significance for practice. Relevant papers might receive a high level of mentions and yet at the same time receive relatively few academic citations.

To explore this hypothesis, interviews were arranged with a diversity of experienced researchers and practitioners, with specific attention to research in medicine and health.

There were three planned stages:

- Speak to key informants and draw on their experienced, professional view of the characteristics of papers that have professional influence, which might refer to particular journals, the style of the paper, keywords or key phrases in abstracts or introductory text. (They may judge that there is no consistent identification pathway.)
- Analyse (individual and clustered) publications for which significant volumes of Altmetric data have accumulated. Deconstruct their characteristics in terms of characteristics discussed with our informants.
- Expose both the input from key informants and the data analysis to a second group of practitioners. Compare papers with high and low Altmetric scores in terms of their indicative characteristics. Discuss whether these findings make sense from an experienced, professional viewpoint and whether this leads to indicators of professional significance.

In practice, this part of the research was wound up after the initial interviews and analysis when it became evident that no consistent distinction could be made between publications on the basis of academic vs professional impact.

Those interviewed included:

Director of a research institute for health and medical practice at a '1994 group' university
Senior policy manager at a foundation with extensive research funding programmes in health and medicine
Former CEO of a heath consultancy, now professorial director of a university policy institute
Strategic director at a publishing house with high-impact biomedical serials
Policy advisor at a leading national medical research charity
Former Dean of a Russell Group medical school, now in university senior management
Policy advisor at World Health Organisation

Former vice-chancellor of Russell Group university, now consultant/researcher on relevant national policy
Director of regional heath body, previously head of university school of health and panel chair in university Research Assessment Exercise