How citation distortions create unfounded authority: analysis of a citation network

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ABSTRACT

Objective To understand belief in a specific scientific claim by studying the pattern of citations among papers stating it.

Design A complete citation network was constructed from all PubMed indexed English literature papers addressing the belief that β amyloid, a protein accumulated in the brain in Alzheimer's disease, is produced by and injures skeletal muscle of patients with inclusion body myositis. Social network theory and graph theory were used to analyse this network.

Main outcome measures Citation bias, amplification, and invention, and their effects on determining authority.

Results The network contained 242 papers and 675 citations addressing the belief, with 220 553 citation paths supporting it. Unfounded authority was established by citation bias against papers that refuted or weakened the belief; amplification, the marked expansion of the belief system by papers presenting no data addressing it; and forms of invention such as the conversion of hypothesis into fact through citation alone. Extension of this network into text within grants funded by the National Institutes of Health and obtained through the Freedom of Information Act showed the same phenomena present and sometimes used to justify requests for funding.

Conclusion Citation is both an impartial scholarly method and a powerful form of social communication. Through distortions in its social use that include bias, amplification, and invention, citation can be used to generate information cascades resulting in unfounded authority of claims. Construction and analysis of a claim specific citation network may clarify the nature of a published belief system and expose distorted methods of social citation.

WHAT IS ALREADY KNOWN ON THIS TOPIC

In addition to its scholarly use, citation has social uses, both self serving and as a tool for persuasion

One distortion of this persuasive aspect of citation, citation bias, has been recognised in clinical trial reporting where it may lead to false belief about a therapy's efficacy

WHAT THIS STUDY ADDS

Distortions in the persuasive use of citation—bias, amplification, and invention—can be used to establish unfounded scientific claims as fact

Categorising these distorted uses of citation and having vocabulary for them aids in their recognition

How scientific data evolve into entire published biomedical belief systems around specific claims can be studied through a device called a claim specific citation network and the use of social network theory

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INTRODUCTION

To understand how a belief system shared by a scientific community evolves from data across papers within a specialty I analysed the example of β amyloid protein, which is known for its role in Alzheimer's disease but has also been claimed to be produced by and injure skeletal muscle fibres in inclusion body myositis. This belief system was chosen partly because this view seems to be accepted by many as likely or established fact (stated in at least 200 journal articles), and directs research and treatment trials for these patients.

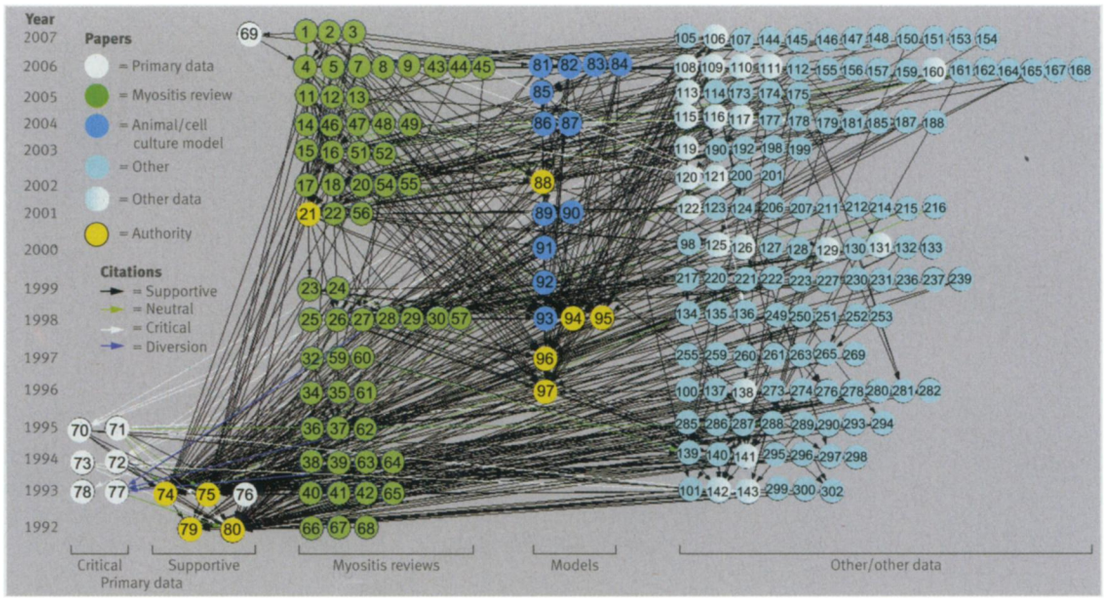
METHODS

The methods are described elsewhere (see web extra note 2). Briefly, queries identified all English language PubMed indexed articles potentially containing statements pertaining to any of three related molecules (β amyloid precursor protein, its transcript, or one of its potential cleaved protein products, β amyloid) and muscle disease. I collected all statements addressing the belief and citations supporting these statements. Papers were classified as primary data (with experimental data addressing the specific and abnormal presence of these molecules in inclusion body myositis muscle), myositis review (with the term myositis or equivalent in the title), model (reporting cell culture or animal experiments), or other. I classified each citation as supportive, neutral, or critical according to how its underlying statement supported the belief. The constructed network was further extended into research proposals funded by the US National Institutes of Health. (See web extra for details of references prefixed with an "s".)

RESULTS

A claim specific citation network was constructed from 242 of 766 potential papers containing statements addressing the claim that β amyloid and its precursors are abnormally and specifically present in inclusion body myositis muscle fibres among many other muscle diseases and the 675 citations supporting these statements (figure). This network contained 220 609 citation paths.

Within networks certain nodes receive large amounts of network traffic, termed "authorities."[1] Under social network theory, authority of a claim indicates the community's net belief about it. By examining the patterns of connections among the nodes,[1] four primary data papers, five model papers, and one review paper constituted the 10 most authoritative papers, all expressing the view that the claim was true.



Claim specific citation network. Citations regarding claim that β amyloid precursor protein mRNA or protein, or β amyloid protein, is abnormally present in inclusion body myositis muscle. The network is organised according to paper category and year of publication. Authority status (yellow) was defined computationally by network theory. Many citations flow to supportive primary data but not critical data. Papers are represented as nodes (n=218) and citations as directed edges (supportive n=636, neutral n=18, critical n=21, diversion n=3). Twenty four papers contain statements pertaining to claim but do not make or receive citations about it (not shown). Paper numbering according to web extra references

Citation bias against critical primary data

Four of the 10 authoritative papers provided experimental data addressing the claim.[s74 s75 s79 s80] They were from the same laboratory, two of which[s79 s80] probably reported mostly the same data without citing each other. These papers had major technical weaknesses, most notably a lack of data on number of affected muscle fibres and a lack of specificity of reagents for distinguishing β amyloid protein from β amyloid precursor protein.

Six primary data papers received no or few citations (figure). These papers contained data refuting or weakening the claim. Three papers[s71 s73 s77] from independent laboratories reported that 28 of 35 patients with inclusion body myositis studied had no affected muscle fibres while the remainder had five or fewer affected muscle fibres. Two papers[s70 s72] by the laboratory that wrote the four authority papers reported that β amyloid precursor protein transcript and protein were not specific to inclusion body myositis but were present in muscle fibres during regeneration in all diseased controls. These findings weaken the view that abnormal amounts of these molecules have any specificity to inclusion body myositis and that they cause degeneration of myofibre in patients with inclusion body myositis. One of these papers[s70] offered an alternative source than myofibre production for the molecules and indicated that β amyloid was non-specifically present in other inflammatory myopathy muscle.

Supportive but not critical data achieved authority over the 12 years since publication (see bmj.com); the supportive papers received 94% of the 214 citations to these primary data, whereas the six papers containing data that weakened or refuted the claim received only 6% (differing citation frequency, P=0.01). Citation bias (statistically significant differences in number of citations received among primary data papers) seemed to be specifically against critical data not the laboratory producing it, as two papers[s70 s72] that were biased against were written by the research group that wrote four of the highly cited supportive papers.

Citation bias to justify models

Citation bias was used to claim that animal and cell culture experiments are valid models of inclusion body myositis, in 17 papers.[s81-s97] Of the 32 citations to primary data from these papers, 31 (97%) flowed to the four highly supportive papers,[s74 s75 s79 s80] whereas only one citation (3%) was made to any of the six papers that presented data weakening or refuting these as valid models (see bmj.com).

Citation diversion

Some papers cited content but distorted it, termed citation diversion. One primary data paper[s77] reported no β amyloid precursor protein or β amyloid in three of five patients with inclusion body myositis and its presence in only a "few fibres" in the remaining two patients. Three papers[s28 s37 s38] cited these data (figure) reporting that they "confirmed" the claim. These data are furthermore exaggerated and generalised into a view that β amyloid precursor protein is "accumulated in vacuolated muscle fibers of s-IBM patients[s77, others]" as stated

by one paper,[s28] supported by an erroneous citation because three patients in one paper[s77] had 1.4% to 5% of their myofibres vacuolated but all lacked β amyloid precursor protein. Over the ensuing 10 years these three supportive citations developed into 7848 supportive citation paths—chains of false claim created by citation diversion.

Amplification through influential papers and citations

Between 1996 and 2007 support for the claim grew exponentially, with the number of supportive citations and citation paths increasing sevenfold and 777-fold, to 636 citations and 220 553 citation paths. In contrast, the critical view grew to only 21 citations and 28 citation paths (see bmj.com). No papers refuted or critiqued the critical data, but instead the data were just ignored. The increased support was facilitated by a small number of papers not reporting any primary data, through which large amounts of traffic flow.

The term amplification describes the expansion of a claim's belief system by citation to papers lacking any data addressing it. Amplification is not inherent to published belief systems. Authors could choose to cite only primary data when making claims, resulting in amplification minimal networks. Amplification of a claim is instead introduced into belief systems through the citing of papers that lack data addressing the claim.

Invention

Certain types of fact developed andspread through the belief system. These facts were not those that arose from restatement of published claims, but rather involved different mechanisms either deliberate or through scholarly negligence, herein called invention. For example, a subclaim (accumulation of β amyloid occurs early and precedes other abnormalities) has variously been stated as hypothesis, likelihood, or fact in 27 papers supported by 37 citations. Nine of these citations (24%), used to support text making these claims, flowed to papers that contained no statement on the temporal relation of β amyloid to other abnormalities in inclusion body myositis muscle (dead end citations). This subclaim transformed from hypothesis to "fact" through citation alone, a process that might be called citation transmutation (see bmj.com). Thus one paper[s5] contained it as fact supporting this statement by citing the paper[s80] where it had only been proposed as hypothesis.

In another form of invention, claims are introduced as fact through a "back door," bypassing peer review and publication of methods and data. This is accomplished by repeated misrepresentation of abstracts as papers.

Bias and invention in National Institutes of Health funded research proposals

Through the publication of papers and the demonstration of these publications as evidence of productivity, the elements of bias, amplification, and invention can be used indirectly to support requests for research funding. To determine if these elements were used directly to support such requests, the network was extended from the PubMed indexed literature into the research sections and bibliographies of National Institutes of Health funded grant proposals containing text addressing the claim.[2] Of 27 grant proposals requested, nine were released by the National Institutes of Health. These seemed to be the proposals most pertinent to the belief system.

Citation bias or invention was present in eight of these proposals (see bmj.com). Of 23 citations to primary data addressing the claim's validity, 20 were made to supportive primary data, two were instances of citation diversion, and one was made to critical content. Invention of fact supported through citation to hypothesis, dead end citation, and abstracts misrepresented as papers were present in these funded proposals. These were sometimes used directly to justify requests for funding of the proposed studies

DISCUSSION

Separate from its scholarly use, citation may be used for self serving purposes[3] or as a tool for persuasion.[4] These aspects of citation might be called social citation. I studied how distortions of the persuasive aspect of social citation may result in unfounded fact. Network theory applied to citation networks constructed from entire paper bibliographies, such as the science citation network,[5] can disclose societal attitudes to journals and specific papers (for example, impact factors), but these networks are not suitable for understanding the foundation for belief in specific claims. When networks are instead confined to citation pertaining to one set of related claims (a claim specific citation network), they become focused tools for understanding social communication pertaining to the claims—what is in effect the published record of a belief system shared by a community.

The general approach taken here (see bmj.com) addressed belief in claims; no experiments were done addressing their truth. The computational analysis of the claim specific citation network representing this belief system detected certain distortions in the patterns of citation that would not have been expected had only scholarly citation been used. Primary data that weakened or refuted claims on which the belief was based were ignored (citation bias) and a small number of influential papers and citations exponentially amplified supportive claim over time without presenting new primary data (amplification). Certain related claims were invented as fact. The combined effects of these citation distortions resulted in authority of the belief (acceptance of it) according to social network theory.

There are varied forms and consequences of distorted persuasive citation seen in this study (see bmj.com). Citation bias against critical content can be used for the systematic support of claim,[6] results in

the loss of implications of isolated data, and can be used to justify construction of animal models, which can then be circularly used to amplify claims. Such animal models have enormous appeal, and some publications describing them achieved authority status in this network (figure) despite reporting no data addressing the claim. Amplification involves repetitive citation of review papers or other papers lacking data, often through self citation, features noted previously in a variation of a claim specific citation network.[7] Invention has multiple variations.

Three factors may account for how citation distortions created authority in this belief system. Foremost is the power of citation through the choice of which papers to cite and which to ignore (citation bias), by citing but distorting content (citation diversion), and by using citation to invent fact (citation transmutation, dead end citation, and back door invention).

Second is an inherent property of negative results, which failed to spread through the network. These were not repeatedly cited by their authors in subsequent papers as perhaps there was simply nothing further to say. The progression from data to accepted claim is different within a single paper compared with across a collection of papers in a specialty. Within a single paper readers generally view new claims as false until proved true through convincing methods and results. Across a network of papers, however, the barrier to the propagation of negative results biases claims as being viewed as true until proved false.

Thirdly, this belief system is possibly an information cascade,[8 9] an entity resulting when people perceive advantage in accepting the prevailing view over any private information they may have when making choices. Many authors may just not be aware of the critical data, as these data are effectively isolated from the discourse about this claim and not mentioned in any review articles. Although unsound information cascades are in theory fragile and fall apart quickly when exposed,[8] this may not occur in biomedical belief systems, where contradicted claims may persist.[10]

Many published biomedical belief systems may be information cascades because repetition of claims is ubiquitous in the biomedical literature. Many are built on sound data, with authors repeating claims after trusting the published expert opinion of their colleagues. However, there are incentives for generating and joining information cascades regardless of their soundness. Joining an information cascade aids publication as articles have to say something and negative results are biased against.[11] Generating and joining an information cascade may improve the likelihood of obtaining funding because hypothesis driven research is an essential requirement[12] at many funding agencies such as the National Institutes of Health, and successful funding generally requires a "strong hypothesis . . . based on current scientific literature"[12]—that is, the published belief system of a claim. Chances for successful funding may therefore be increased through joining the cascade (repeating the claim and proposing experimental plans around it). In the extension of this citation network into text funded by National Institutes of Health research grants, citation bias, diversion, or invention were often present. Once research funding has been used to join a cascade there are further incentives to interpret results through confirmation bias to demonstrate success of the research for subsequent funding. Although joining an information cascade may be an optimal behaviour for some people, it reduces the likelihood that future investigators can discover whether it is sound.[9]

Methods for the construction and analysis of comprehensive claim specific citation networks present challenges and limitations. These include interpreting meaning of text, as people may reasonably interpret text differently, and understanding the distinct phenomena observed. In principle many biomedical claims have an associated citation network, the study of which provides a powerful approach to detecting citation bias, amplification, and invention, and understanding the nature of the authority of the claim.

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Competing interests: SAG had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Ethical approval: Not required.

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