# 8 The amplification of uncertainty: The use of science in the social media by the anti-vaccination movement

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Two relatively recent developments are, in one way or another, changing the science communication environment. The first is the progression towards a more accessible science (Friesike et al., 2015; Leonelli et al., 2015) while the second is the pervasiveness of the social media in our daily lives (Schäfer, 2017; Southwell, 2017; Williams, 2018). Both take place in a broader social context of persistently high levels of distrust in public institutions (Edelman Trust Barometer, 2019; Ortiz-Ospina & Roser, 2016; Winowatan et al., 2019) and new networked social configurations (Castells, 1996, 2009). Some suggest that we are witnessing, in some cases at least, the pollution of the science communication environment (Kahan, 2016). Others express concern over the strategic use of science in the social media for political and economic ends (Weingart, 2017).

The chapter begins with a discussion on communication networks, trust, open science and the norms of science to frame its overarching line of enquiry, i.e. the observable effects of the intersection between science and the social media as they relate to the communication of science. The case of the anti-vaccination movement is put forward as appropriate to explore this intersection because the movement is attentive to science (Bean, 2011; Bennato, 2017; Kata, 2012; Moran et al., 2016) and because

its use of scientific information in its online communications presents very real health risks to society (WHO, 2019).

## Communication networks

In 2018, those on social media networks numbered 2.23 billion active users on Facebook[1] (Statsita, 2018) and 335 million on Twitter[2] (Statista, 2018). Digital media and infrastructure create an integrated, networked environment based on flows of information. Increasingly, this environment provides the primary setting for human agency (Castells, 1996, 2009).

According to Castells, the basic elements of the network society are not material, but the intangible flows of information produced by and processed through media: Information to communicate among people, to control processes, to check and re-evaluate existing information, and to produce more and new information (Stalder, 2006).

It is not that networks are new but that digital information networks introduce new realities of communication and therefore, by implication, of social relations. The space of flows brings distant elements (things and people) into an interrelationship that is characterised by being continuous and in real time (Castells, 1996). From a historical perspective, this conflation of spatial and temporal separation is new.

According to Castells (2009), there are multiple global communication networks, the contours of which are not always sharply defined. Networks overlap and are influenced by one another, and networks compete and defend themselves. One cannot therefore understand one network without reference to other networks, although Castells argues that it is the global financial network that dominates in the current global capitalist economic dispensation (Castells, 2009).

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1 As at the second quarter of 2018.

2 Ibid.

A network is defined by the program that assigns the network its goals and its rules of performance; in other words, the core logic of the network. A network's program consists of codes for the evaluation of performance and criteria for success or failure in the network. To transform the outcomes of any specific network, a new program emanating from outside the network must displace the existing program of the network, and control over communication is a key determinant in the outcome of any attempted displacement (Castells, 2009).

For science, the emergence and entrenchment of digital communication networks in society have had a series of impacts on its communication. The digitisation of the traditional print media and the advent of online social networks have disrupted the communication of science (Brossard, 2013; Scheufele, 2013; Southwell, 2017) and are likely to continue. As socially constructed space, the relationships between social actors (and objects) in the networks of communication in the age of information is therefore key to understanding the delivery, reception, use, re-use and impact of science communication.

## Trust in science

Referring specifically to science, Popper (1962) also attributes the acquisition and application of the capacity to recognise science to an immersion in a set of social processes and conventions. Any influence that impairs or impedes these social practices will degrade the ability of the public to recognise valid science and hence to fully realise its benefits. The key concepts at work are influence and validity, and both are strongly linked to trust.

How trust is established between science and its publics is poorly understood (Scheufele, 2014; Weingart & Guenther, 2016). Schäfer (2016) argues for a greater acknowledgement within the field of science communication of the role that trust plays in the intermediation process of communicating science. Weingart and Guenther (2016) argue that trust is in part a factor of intent in relation to the public good. Those whose intentions are

in the public interest (for example, firemen) are trusted more than those perceived to harbour intentions that are self-promoting (for example, politicians). But the markers or social cues for establishing trust aren't always visible (Lin, 2008) or may be replaced with new cues when the communication of science is interpersonal as is the case in the social media (Southwell, 2017). It remains an open question why publics are receptive to the communications of selected non-scientific intermediaries in such networks, although some suggest a new conceptualisation of power in the form of the influence wielded by intermediaries in the network society (Muller 2017).

The media have traditionally been the primary interface between science and the public (Weingart, 2011), and it is the science journalist who has traditionally kept the public informed on the latest developments from the world of science (Schäfer, 2017). There has, however, been a decline in science journalism (Scheufele, 2013; Schäfer, 2017), an increase in the clamour for attention among a variety of would-be network programmers (Weingart & Guenther, 2016; Williams 2018), and an emergence of informal, interpersonal communication between science and its publics via social media (Southwell, 2017). Individuals and minority groups broadcast their own content, and attract and surpass the levels of attention garnered by the mass media because of the ubiquity of online communication networks such as Twitter, Facebook, YouTube and Instagram (Schäfer, 2017; Southwell, 2017) as well as the propensity of their programmers to capture our attention (Williams, 2018; Wu, 2016).

Bucchi (2018) describes this scenario as a 'crisis of mediators'. Scientific research and information are increasingly fed in real time into the public domain without being filtered by communication professionals. Unfiltered (open) science communication is directly connected to populism and social trends. As a consequence, the non-scientific public must be highly adept at discerning which communication sources of scientific information to trust (Kahan et al., 2017; Scheufele, 2013).

The verification of information flowing in communication

networks cannot always not take place; recipients take information presented to them at face value. The reason for this is a structural condition of networks – the logic or programme of the network may determine that information must flow not only constantly but rapidly, negating the possibility for fact-checking and/or deferred decision-making (Stalder, 2006). Instead of an increase in trust between actors in communication networks, trust is implicit in certain communication networks because the network demands it (Stalder, 2006).

In the case of some communication networks, trust mechanisms may be created purposefully to allow information injected into the network to be taken at face value. For example, in the global financial network, the clearing house institutionalises a system of trust designed to protect the network against external threats. Without this buffer, the exchange of information would slow down considerably because the validity of the information would have to be verified outside the network itself. The clearing house in the global financial network therefore protects the constant flow of information from being interrupted by external events which would compromise the face value of the information. Networks other than the global financial network require similar central, trusted nodes that intermediate information to ensure the functioning and the survival of the communication network.

Active, trusted nodes intermediate to ensure the functioning and the survival of the communication network by guaranteeing that information can be taken at face value (Stalder, 2006).

## Open science and the norms of science

The increase in advocacy for transparency and accountability, operationalised as openness and access, stems in part from a degradation of trust in public institutions (Edelman Trust Barometer 2019; Ortiz-Ospina & Roser, 2016; Winowatan et al., 2019). This includes those institutions tasked with conducting scientific research and innovating for the development of society. The

breakdown of trust in institutions has also seen the rise of new public management and the escalation of quality assurance models of organisational control (Power, 1997, 2000; Taubert & Weingart, 2017). The demands for accountability through greater transparency, oversight and measurement of public institutions are buttressed by claims of beneficial returns to society (Weingart, 2012). Open science is, from such a vantage, seen as being a necessary evolution towards improvement in the efficiency, quality and relevance of science to society (Jasanoff, 2006; Leonelli et al., 2015).

From a historical perspective, Eamon (1985) argues that there was a progressive shift from a more secretive to a more public science from the 17th century onwards, accelerated by the disruptive technology of the printing press and a concomitant reaction against hierarchical and monopolistic knowledge systems. Following, among others, the influence of science reformers such as Bacon and Hartlib; the establishment of Théophraste Renaudot's *Bureau d'adresse* in Paris in 1633 and of the Royal Society of London in 1662; and the publication of the *Philosophical Transactions* in 1665, the institutional mechanisms that would govern science as a form of 'public knowledge' were in place. According to Eamon (1985: 346), 'the ideal of public knowledge was not taken to imply then – any more than it does today – that everyone had perfectly free access to scientific knowledge. Nevertheless, the institutionalisation of science under the auspices of the Baconian programme helped to confirm the scientist's special role in society, not as the guardian of secret knowledge, but as the purveyor of new truths bearing the authority of experimental evidence. Free communication within the scientific community became the norm'.

By the mid-20th century, sociologist Robert Merton (1973) had proposed four norms guiding the social behaviour of scientists, one of which, the norm of communalism, dictates that the results and discoveries of science are not the property of the individual researcher but belong to the scientific community and to society at large. More recently, with the rise of the information age, the discourse around 'openness' has predominantly been in opposition to the extractive and restrictive positioning of knowledge as a

private good (Boyle, 2003; Chan & Costa, 2005). The opposition is based on the premise that the sharing and reuse of science has become less dependent on the services offered by intermediaries such as publishers. Proponents of open science have emerged in opposition to the 'enclosure' of the products of science, or at least to their control by third parties, and advocate instead for their reuse without the impediments of cost and permissions (Evans, 2005).

While the open science movement mobilised with transformative intentions, it is not immune to commercial interests (Lawson, Gray & Mauri, 2016; Taubert & Weingart, 2017). As a result, there is a counter-movement towards utilitarian and instrumentalist 'openness', with less of a focus on the potential of openness for the advancement of science, and an increased emphasis on business models designed to mine openness and extract material value (Taubert & Weingart, 2017).

The norm of organised scepticism in science implies that all formal communication is provisional and contested, and it is common practice for majority as well as minority groups of scientists to self-organise themselves in relation to truth claims made by their peers. As in any functioning democracy, the majority tends to hold power. Choosing, temporarily at least, not to take sides, there is invariably a group of undecideds. However, when minority groups are able to leverage new communication technologies to amplify their message and garner unprecedented levels of attention in relation to their size, the likelihood of swaying the undecideds increases. In the much-publicised case of voter manipulation by Cambridge Analytica using Facebook data and aggressive and highly targeted online campaigning, this group of undecideds is described as 'the persuadables' (Amer & Noujaim, 2019).

Swaying the persuadables is less likely to play out within the scientific community because of its self-imposed system of checks and balances; a system that is self-regulated because scientists value a taken-for-granted and shared objective despite any floor crossing and factionalism: the establishment of verified truths. However, external to the scientific community, the safety

net of truth-seeking falls away as publics arrange themselves into majority and minority positions around contentious social issues. The undecideds are targeted with persuasive messaging by the minorities seeking to swell their numbers; and unlike in the domain of science, the common objective of truth-seeking is replaced by ideological objectives which are agnostic to the norms of science.

## New potentials in the communication of science

In politics, the potential to harvest data from social media networks, and to use those same social networks to influence the outcomes of democratic processes, has been uncovered (Amer & Noujaim, 2019; Illing, 2018; Tharoor, 2018). In the world of finance, unscrupulous investment companies target the reputations of large, listed public companies and use the network effects of online communication media to profit from short selling (Cameron, 2018). If online communication networks can be deployed to disrupt politics and finance, then it seems reasonable to ask what the potentials are for science.

However, an unquestioning faith in the potential of technology to advance society mutes the concerns expressed by socially-attuned observers. Referring to the founders of Google and Facebook as examples, Naughton (2017: n.p.) reports that 'it never seems to have occurred to them that their advertising engines could also be used to deliver precisely targeted ideological and political messages'. The founder and ex-CEO of Twitter, Even Williams, has lamented the use of the platform for unintended, confrontational and nefarious purposes by some of its users (Streitfeld, 2017).

Absent in much of the science communication literature are the potential risks of the communication of science in the online networked communication environment, although there are signs that a consideration of the risks is emerging (Bishop, 2016; Dickel & Franzen, 2016; Jasanoff, 2006; Lewandowsky & Bishop, 2016). Where the effects or impacts are considered, the emphasis is often on science itself, and on the beneficial impacts (Bishop,

2016). What should be of concern to science, as it becomes more open to its publics, are non-scientific, ideologically-motivated publics who are able to access knowledge-in-progress as part of their communication strategies aimed at destabilising established truths. Such risk may outweigh the benefits. As Jasanoff (2006: 36) writes: 'When claims have arrived at a certain degree of robustness, then asking for renewed scrutiny of the ways in which those conclusions were reached strikes many observers not as justifiable curiosity but as 'manufacturing uncertainty' for political ends. When public health and safety are at stake, such needless production of uncertainty could be not entirely frivolous but downright dangerous.'

## An attentive anti-vaccination movement

An example of both the amplitude and risks made possible by online communication networks is to be found in the strategies employed by the anti-vaccination movement that has shown itself to be highly attentive to science (Moran et al., 2016).

In 2005, researchers were already aware of how the 'damage' could be escalated by online communication (Zimmerman et al., 2005). According to DiResta and Lotan (2015: n.p.), '[t]his anti-vax activity might seem like low-stakes, juvenile propaganda. But social networking has the potential to significantly impact public perception of events – and the power to influence opinions increasingly lies with those who can most widely and effectively disseminate a message. One small, vocal group can have a disproportionate impact on public sentiment and legislation.' Zimmerman et al. (2005: n.p.) state that '[w]ith the burgeoning of the internet as a health information source, an undiscerning or incompletely educated public may accept these claims and refuse vaccination of their children. As this occurs, the incidence of vaccine-preventable diseases can be expected to rise'. A legitimate concern given that 15 years later, the WHO (2019) has listed vaccine hesitancy as one of the top ten global health threats.

Scientists warn that what may seem like negligible decreases in

vaccination rates can have dire health outcomes as herd immunity is compromised (Lo & Hotez, 2017). Of equal concern is that while on average vaccine rates in a country such as the US have remained stable at around 90%, the perception held by the general population is that vaccination rates are in the 70–79% range (Kahan, 2014). In countries as varied as France, Russia, Japan, Italy, Greece, Iran and Vietnam, more than 20% of the population believe vaccines to be harmful (Larson et al., 2016). These are worrying statistics given that the herd immunity threshold for most available vaccines is higher than 80%.

Changing perceptions and behaviour do not fully account for changes in vaccination rates. Constraints in the supply of vaccinations also impact vaccine coverage (Vanderslott & Roser, 2018). Nevertheless, given the evidence available, the role of communication in shaping perceptions and amplifying anti-vaccination messaging cannot be ignored; particularly if, as the US CDC suggests, 'philosophical objections' rather than supply constraints accounted for 79% of measles vaccination refusals in 2012 (CDC, 2013).

Given changes in the science communication environment and possible risks for both science and society, this chapter seeks to answer the following questions with a focus on the anti-vaccination movement: Is the anti-vaccination movement making use of scientific information in its online communications? If so, how is the movement using scientific information to promote its cause?

## Methodology[3]

To determine the use of scientific information by the anti-vaccination movement in its online communications, open access journal articles on the relationship between vaccines and autism[4] were

3 See Van Schalkwyk (2019) from a more comprehensive account of the methods used in this study.

4 This specific focus on the link between vaccination and autism is supported by Moran et al.'s (2016) findings that 65.8% of 480 anti-vaccination websites in their study focused specifically on autism as a disease associated with vaccines.

identified by conducting searches of online repositories of scientific publications, by joining a known anti-vaccination Facebook group and by following an active anti-vaccination Twitter account. Limiting the selection to open access journal articles ensured that none of the articles were restricted regarding the accessibility of its content and was in keeping with the research objective of investigating the possible risk of open science.

From the sample of relevant open access journal articles, 10 were selected for closer analysis. Articles were selected in equal proportion from the online repositories (articles 1.1 to 1.5) and from the mentions of anti-vaccination accounts in the social media (articles 2.1 to 2.5). These 10 articles were selected based on their levels of online attention as indicated by each article's Altmetric Attention Score[5] (see Table 1).

Two online spheres – Twitter and the web – were analysed independently, and with some variation in the analysis owing to different affordances of each sphere, to discover whether and how those scientific articles are being used by the anti-vaccination movement.

In the case of Twitter, accounts were first categorised according to their stance (that is, whether they are anti-vaccination accounts). Thereafter, the level of activity and engagement of anti-vaccination accounts for each of the most frequently mentioned articles was determined. In the case of the web, the stance of the authors of anti-vaccination pages was already known and level of activity could not be quantified in a manner possible for the social media. Web pages were therefore only analysed for level of engagement.

The approach adopted to assess level of engagement with scientific information from open access journal articles was an attempt to go beyond views, downloads or mentions as proxies for the use of online content (Thelwall et al., 2013).

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5 The Altmetric Attention Score is an automatically calculated, weighted count of all of the attention a research output has received across 15 different online media. For a detailed breakdown of the weightings and how the score is calculated, see https://help.altmetric.com/support/solutions/articles/6000060969-how-is-the-altmetric-score-calculated-

Table 1: Open access journal articles selected for analysis

| Ref. | Title of open access journal article | Altmetric Attention Score |
|---|---|---|
| 1.1 | Imperfect vaccination can enhance the transmission of highly virulent pathogens | 511* |
| 1.2 | Prevalence and characteristics of autism spectrum disorder among children aged 8 years – Autism and Developmental Disabilities Monitoring Network, 11 Sites, United States, 2012 | 311* |
| 1.3 | Lack of association between measles virus vaccine and autism with enteropathy | 306* |
| 1.4 | GWATCH: A web platform for automated gene association discovery analysis | 113* |
| 1.5 | The evolutionary consequences of blood-stage vaccination on the rodent malaria *plasmodium chabaudi* | 96* |
| 2.1 | Autism occurrence by MMR vaccine status among US children with older siblings with and without autism | 3,674# |
| 2.2 | Vaccines are not associated with autism: An evidence-based meta-analysis of case-control and cohort studies | 2,989+ |
| 2.3 | A positive association found between autism prevalence and childhood vaccination uptake across the US population | 1,336+ |
| 2.4 | Measles-mumps-rubella vaccination timing and autism among young African-American boys: A reanalysis of CDC data | 1,048+ |
| 2.5 | A two-phase study evaluating the relationship between thimerosal-containing vaccine administration and the risk for an autism spectrum disorder diagnosis in the United States | 1,018+ |

# As at 17 October 2017 * As at 18 October 2017 + As at 24 October 2017

In the subsections that follow, the methods of analysis for Twitter and web pages are described in detail.

## Stance, activity and level of engagement on Twitter

Twitter data collected from the Altmetric Explorer for the 10 open access journal articles were analysed to determine (1) the number of mentions by an anti-vaccination account, (2) the number of tweets by anti-vaccination accounts, and (3) the level of engagement by anti-vaccination accounts.

The first task was to determine which of the Twitter accounts

mentioning the journal articles could be classified as 'anti-vaccination'. From the Altmetric.com data, it was possible to create a list of unique Twitter accounts mentioning each of the 10 journal articles. A programmer was commissioned to develop an application[6] that could crawl the Twitter account URLs for each article. The crawler queried each Twitter account URL for a predetermined set of terms or hashtags commonly used by the anti-vaccination movement: antivax, vaxxed, vaccineinjur, vaxfax, vaccinesafety, informedconsent, vactruth. The selection of these terms was determined by: (1) their identification in previous studies investigating the use of Twitter in the anti-vaccination debate (Dredze et al., 2017; Mitra et al., 2016; Radzikowski et al., 2016); (2) additional terms noted by the researcher while creating the sample of anti-vaccination web pages referring to scientific research;[7] and (3) the frequency with which the terms are used on Twitter as indicated by Symplur Signals.[8]

The application returned the number of times each term could be found for each of the URLs. The presence of one or more hashtags was taken to indicate that a Twitter account associated with the URL is, most likely, anti-vaccination. The crawler only detects Twitter terms or hashtags that appear on the first page of a Twitter account. If an account used the hashtags in the past and those hashtags no longer appear on the first page of the account, then the URL will not return a positive result. Similarly, accounts that do not use the prescribed hashtags may nevertheless be anti-vaccination. These limitations of the crawler application mean that the crawler's results are conservative estimates of the number of likely anti-vaccination Twitter accounts.

The possibility also exists that accounts for which the crawler returns positive results may in fact be false positives because some

6 See https://dev.sbc4d.com/cdv/fsv/geturl.php

7 Milani (2016) also finds that despite the many tools available for identifying and analysing Twitter hashtags, some are still only discovered by chance in the research process. Mitra et al. (2016) point out that due to the transient nature of social media, it is not possible to rely solely on terms found to be in common use in the past.

8 See https://signals.symplur.com

pro-vaccination Twitter accounts use hashtags commonly used by the anti-vaccination movement to lure anti-vaccination accounts into an exchange (Conover et al., 2011). To account for false positive results, all positive results returned by the crawler were checked manually, and all accounts found to be pro-vaccination were recorded as such and removed from the sample.

Each account identified by the crawler was coded as either 'anti', 'pro', 'neutral' or 'unknown'. An account was deemed to be anti-vaccination if any consistent anti-vaccination sentiment was expressed in the Twitter account description, in the banner image of the account or in the most recent tweets on the first page of the account, or, failing the availability of an informative description, based on the sentiment expressed in a linked website, blog post or online document. An account was coded as neutral only if an explicit statement was found indicating impartiality and there was evidence of posts representative of both sides of the vaccination debate. Accounts were coded as unknown when it was not possible to make a determination regarding stance.

To determine the proportion of tweets attributable to anti-vaccination Twitter accounts, the anti-vaccination Twitter accounts were compared to the list of all accounts and tweets as recorded in the Altmetric.com data.

For some of the articles in the sample, Twitter mentions were found to be low. The levels of engagement analysis was therefore limited to those articles frequently mentioned by anti-vaccination accounts on Twitter, that is, articles 2.3 (812 anti-vaccination tweets); article 2.4 (672 anti-vaccination tweets) and article 2.5 (545 anti-vaccination tweets). For practical reasons, not all Tweets could be analysed for level of engagement. A simple random sample of 100 anti-vaccination tweets was generated for each of the three articles.

The determination of the level of engagement on Twitter by the anti-vaccination movement was done by reading each tweet in the Altmetric Explorer datasets for the three open access journal articles. Each Tweet was analysed using a 6-point scale of engagement. The scale was developed based on the suggestion by

Haustein et al. (2016) that those actions on the web that result in online visibility and traceability be categorised along a continuum of access, appraisal and application.

In an earlier study on the identification of Twitter audiences, Haustein and Costas (2015) also set out to measure the degree to which audiences engage with tweeted journal articles. They excluded retweets and use the dissimilarity between the content of the tweet and the title of the journal article as an indicator for engagement. They provide as reason for this approach the fact that only original content constitutes engagement and also that automated bots are frequent retweeters. The scale for level of engagement developed in this study departs from such an interpretation of retweets because although retweets indicate a low level of engagement, they nevertheless are assumed to play an important role in the online communication strategies of social movements.

Progression from access to application on the engagement continuum indicates increased levels of engagement by actors with digital objects such as web pages, images, journal articles, datasets and the like. An article may generate many tweets and retweets that mention an article, but such activity may not be the result of the content of the article. For example, a retracted article may generate many mentions to the article in relation to its retraction, but such activity is not necessarily indicative of engagement with the content of the article. The scale for level of engagement attempts to measure increasing levels of engagement in relation to the content of each article rather than in relation to the degree of activity on Twitter.

The scale was tested and refined using tweets for article 1.1 in order to produce the scale in Table 2.

Tweets that no longer existed or to which access was restricted by Twitter, were included in the sample of 100 tweets but could not be analysed for obvious reasons.

Table 2: Scale for level of engagement with journal articles in anti-vaccination tweets

| ENGAGEMENT → | | | | | |
|---|---|---|---|---|---|
| ACCESS | | APPRAISAL | | APPLICATION | |
| 1 LOW | 2 LOW | 3 MEDIUM | 4 MEDIUM | 5 HIGH | 6 HIGH |
| Retweet OR Tweet that is copied from an earlier tweet OR broadcasting existing tweet to other accounts | Tweet article title OR tweet link and hashtags OR reply to existing tweet with link and hashtags | Tweet direct quotation from article abstract or summary | Tweet a description of the article findings in own words OR a direct quotation from the body of the article | Tweet consists of an interpretative statement or graphic pertaining to the article content | Tweet consists of an interpretative statement followed by a discussion thread consisting of at least a reply from another user and a response from the author of the tweet in which content from the article is used to substantiate the author's position |

## Level of engagement on the web

Using snowball sampling by following anti-vaccination accounts on the social media, 167 web pages were identified that made reference to a scientific source of one type or another. Of these, 70 pages included article digital object identifiers (DOIs) or PubMed IDs but only 34 web pages provided either DOIs or PubMed IDs to *full-text* open access journal articles.

The determination of level of engagement by members of the anti-vaccination movement with open access journal articles via web pages was done by developing a 6-point scale of engagement that corresponds as closely as possible to the scales used to analyse engagement on Twitter, while taking into account differences in how content is constructed and shared on social media and web pages. As with engagement on Twitter, the scale was developed based on Haustein et al.'s (2016) suggestion that engagement on the web be categorised along a continuum of access, appraisal and application, and that progression from access to application indicates increased levels of engagement by actors with digital objects. The scale was tested and refined using three randomly selected web pages. The final 6-point scale used is presented in Table 3.

Table 3: Scale for level of engagement with journal articles on anti-vaccinations web pages

| ENGAGEMENT → | | | | | |
|---|---|---|---|---|---|
| ACCESS | | APPRAISAL | | APPLICATION | |
| 1 LOW | 2 LOW | 3 MEDIUM | 4 MEDIUM | 5 HIGH | 6 HIGH |
| Republication (repost) of a previously published article or blog | Includes only the title or a direct quotation from the article abstract as a reference to the article | Includes only a direct quotation from the article abstract, plus comment(s) by the author | Includes a description of the article in own words AND/OR a direct extract from the body of the article | Includes an interpretative statement/ narrative, table or graphic pertaining to the article | Includes an interpretative statement/narrative, table or graphic pertaining to the article followed (1) by a discussion thread consisting of at least a reply from another user and a response from the author of the web page in which content from the article is used to substantiate the author's position OR (2) references to and reasoned counter-arguments to pro-vaccination articles |

It is important to note that the scale for level of engagement on the web does not in any way attempt to measure or assess the validity of arguments presented by the anti-vaccination movement with reference to open access scientific journal articles; the scale only seeks to measure the level of engagement with the content of those scientific articles in the construction of arguments. Only web pages written in English were analysed for level of engagement.

## Findings

The findings are presented in two parts. The first part relates to mentions made specifically by the anti-vaccination movement to 10 open access journal articles. This part includes findings on the relative size and activity of the anti-vaccination movement on Twitter and addresses the question of whether the anti-vaccination movement is in fact using scientific content in its online communications. The second part presents findings on the use of open access journal articles on Twitter and web pages by applying level of engagement as a proxy for use. The findings presented in

this second part of the section address the question about how the anti-vaccination movement is using openly accessible scientific content in its online communications.

## Mentions of 10 open access journal articles on Twitter

Disaggregation of attentive publics on Twitter was done by determining the number of anti-vaccination Twitter accounts in each sample of all Twitter accounts that mention one of the 10 journal articles. The findings in Table 4 show that the proportion of anti-vaccination accounts to all accounts mentioning one of the 10 articles did not exceed 18%. In other words, no more than 1 in 5 mentions to an open access journal article related to the autism-vaccination debate originated from Twitter users whose stance is anti-vaccination. The findings do nevertheless confirm that the anti-vaccination movement is accessing scientific information from open access journal articles, and inserting this information into their online communications.

**Table 4: Anti-vaccination Twitter accounts mentioning an open access journal article on the topic of vaccination and autism**

| Article | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 |
|---|---|---|---|---|---|---|---|---|---|---|
| No. of unique accounts | 310 | 123 | 58 | 81 | 25 | 3 187 | 2 775 | 1 567 | 931 | 1,397 |
| No. of verified anti-vaccination accounts | 36 | 1 | 1 | 0 | 4 | 35 | 40 | 218 | 166 | 157 |
| % anti-vaccination accounts | 11.6% | 0.8% | 1.7% | 0% | 16.0% | 1.1% | 1.4% | 13.9% | 17.8% | 11.2% |

Table 4 also shows that articles mentioned fall into two broad groups: one group of 5 articles (1.1, 1.5, 2.3, 2.4 and 2.5) in which the mentions by anti-vaccination accounts was found to be between 11% and 18% relative to all unique accounts mentioning the article on Twitter, and a second group of 5 articles (1.2, 1.3, 1.4, 2.1 and 2.2) in which fewer than 2% of mentions originated from anti-vaccination accounts.

Table 5 shows that based on textual analysis of article titles and abstracts (Van Schalkwyk, 2019), there is a relationship between the proportion of anti-vaccination accounts mentioning an article and the indicative stance of the article vis-à-vis vaccination. Unsurprisingly, those articles whose titles and findings are clearly supportive of an anti-vaccination stance are more likely to be mentioned by the anti-vaccination movement than those articles that provide no support or contradict an anti-vaccination stance.

Table 5: Vaccination stance of 10 open access journal articles and proportion of Twitter anti-vaccination accounts mentioning the article

| Article ref. | Indicative stance: Title | Indicative stance: Findings | % of anti-vaccination Twitter accounts that mention the article |
|---|---|---|---|
| 1.1 | ANTI-VAC | ANTI-VAC | 11.6 |
| 1.2 | NEUTRAL | PRO-VAC | 0.8 |
| 1.3 | PRO-VAC | PRO-VAC | 1.7 |
| 1.4 | NEUTRAL | NEUTRAL | 0.0 |
| 1.5 | ANTI-VAC | ANTI-VAC | 16.0 |
| 2.1 | NEUTRAL | PRO-VAC | 1.1 |
| 2.2 | PRO-VAC | PRO-VAC | 1.4 |
| 2.3 | ANTI-VAC | ANTI-VAC | 13.9 |
| 2.4 | ANTI-VAC | ANTI-VAC | 17.8 |
| 2.5 | ANTI-VAC | ANTI-VAC | 11.2 |

## Number of tweets mentioning 10 open access articles

Further analysis of the data is possible to determine the proportion of tweets (as opposed to accounts) by the anti-vaccination movement which mention of one of the 10 open access journal articles.

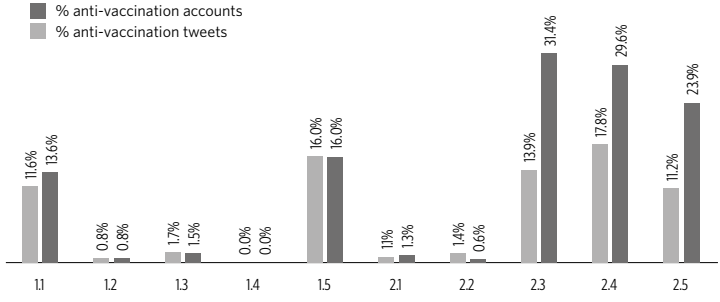
Table 6 shows the proportion of tweets by the anti-vaccination movement compared to all tweets that mention one of the 10 open access journal articles. The proportion of tweets varies by article and again present in two distinct groups that correspond with the two anti-vaccination Twitter account groups.

Table 6: Anti-vaccination tweets

| Article | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 |
|---|---|---|---|---|---|---|---|---|---|---|
| Total no. of tweets | 382 | 131 | 69 | 93 | 25 | 3 551 | 3 509 | 2 589 | 2 268 | 2 282 |
| No. of anti-vaccination tweets | 52 | 1 | 1 | 0 | 4 | 45 | 21 | 812 | 672 | 545 |
| % of anti-vaccination tweets | 13.6% | 0.8% | 1.5% | 0% | 16.0% | 1.3% | 0.6% | 31.4% | 29.6% | 23.9% |

Figure 1 compares the proportion of anti-vaccination Twitter accounts with the proportion of anti-vaccination tweets for each of the 10 articles. The graph shows that for those articles that appear to be of interest to the anti-vaccination movement (that is, articles 1.1, 1.5, 2.3, 2.4 and 2.5), the proportion of tweets by the anti-vaccination movement is equal to or higher than the proportion of anti-vaccination Twitter accounts for the same open access journal article. The difference is most pronounced in the cases of articles 2.3, 2.4 and 2.5.

Figure 1: % of anti-vaccination accounts compared to % of anti-vaccination tweets by article

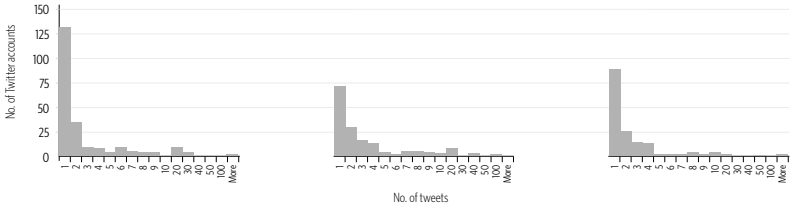



It is possible to determine which Twitter accounts are the most active in the sample of unique anti-vaccination accounts mentioning the three most frequently mentioned open access journal articles (that is, articles 2.3, 2.4 and 2.5). Figure 2 shows the frequency with which each unique account tweeted a mention to the article. There were 218 unique Twitter accounts mentioning article 2.3 in

812 tweets (Figure 2a); there were 167 unique Twitter accounts mentioning article 2.4 in 672 tweets (Figure 2b); and there were 157 unique Twitter accounts mentioning article 2.5 in 545 tweets (Figure 2c).

The data in Figure 2 show a skewed distribution in which the majority of Twitter accounts mention an article only once. The data also show that for all three articles, there are a few accounts that mention the article more than 10 times, and in all three cases there is one Twitter account that mentions the article 100 or more times.

Figure 2: Frequency of mentions by unique accounts on Twitter




(a) Article 2.3 (n=812) (b) Article 2.4 (n=672) (c) Article 2.5 (n=545)

## Mentions of open access journal articles on the web

During the sampling process, 75 mentions by 34 anti-vaccination web pages to full-text open access journal articles were found. This provides evidence (1) that the anti-vaccination movement is making reference to open access journal articles from its web pages, and (2) of the *potential* use of open access journal articles to support its ideology and political agenda. It is to the use of open access journal articles by the anti-vaccination movement that the next section turns its attention.

## Level of engagement on Twitter

Based on the findings of the anti-vaccination movement's activity on Twitter, only three articles were selected to assess the movement's level of engagement: 2.3, 2.4 and 2.5. The selection

of these three articles was determined by the fact that they are the articles that garnered the most attention from the anti-vaccination movement on Twitter.

The findings for the levels of engagement with on Twitter are shown in Figure 3. Figure 3a shows that the distribution of scores for level of engagement with Article 2.3 on Twitter fell predominantly in the access category: 90 (98%) tweets scored either 1 or 2 on the scale. Only 2 tweets fell in the appraisal category. Figure 3b shows that the distribution of scores for level of engagement with Article 2.4 on Twitter fell predominantly in the access category: 85 (98%) tweets scored either 1 or 2 on the scale. Only 2 tweets fell in the appraisal category. Figure 3c shows that the distribution of scores for level of engagement with Article 2.5 on Twitter fell predominantly in the access category: 87 (96%) tweets scored either 1 or 2 on the level of engagement scale. Only three tweets fell in the appraisal category and one tweet was found to show engagement at the level of application.

In all cases, level of engagement with the content of the three open access journal articles was found to be low. Low levels of engagement are attributable to the large proportion of retweets and reposts[9] as shown in Figure 4. In the case of article 2.3, there were 40 retweets (43%) and 31 reposts (34%). In other words, of the 92 tweets, only 21 (23%) consisted of original content. As in the case of Article 2.3, the low level of engagement with article 2.4 is explained by the finding that many of the tweets were either retweets (51, 59%) or reposts (9, 10%). Of the 87 tweets by the anti-vaccination movement, only 27 (31%) consisted of original content. The overall low level of engagement with article 2.5 is again explained by the finding that many of the tweets were either retweets (58, 64%) or reposts (19, 21%). In other words, of the 91 tweets, only 14 (15%) consisted of original content thereby limiting the possibility of higher levels of engagement.

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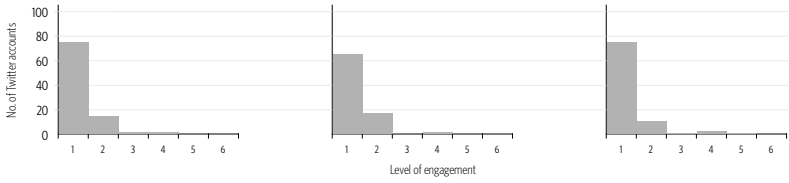
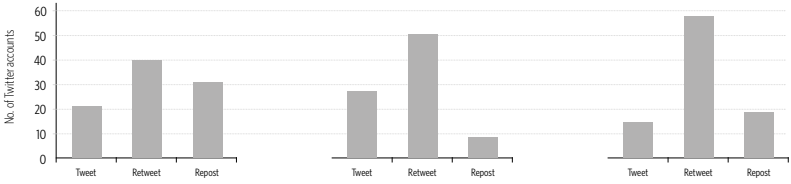
9 A repost is defined as occurring when an account creates a new tweet or a comment that uses the exact same content as a previous tweet by the same account. A retweet occurs when an account clicks on the "retweet" affordance of an existing tweet.

Figure 3: Level of engagement on Twitter




(a) Article 2.3 (n=92) (b) Article 2.4 (n=87) (c) Article 2.5 (n=91)

Figure 4: Tweets, retweets and reposts as an indicator of engagement




(a) Article 2.3 (n=92) (b) Article 2.4 (n=87) (c) Article 2.5 (n=91)

Three observations can be made in relation to level of engagement by the anti-vaccination movement with reference to Article 2.4. The first is that many of the tweets for this article do not relate to its content per se but to the fact that the article was retracted: 'An expression of concern has been published for this article. This article has been retracted. See Transl Neurodegener. 2014; 3: 22'.[10] See Figure 5 for an example of a tweet on the retraction of the article. The motivation behind these tweets is to 'prove' collusion between the CDC, the pharmaceutical industry and scientists, and there is consequently little engagement with the actual content of the article.

The second observation is the number of tweets providing an alternative link to the article post-retraction (see Figure 6). The intent of these tweets is to inform the community that the article remains accessible and, as such, available to them to support their campaign regardless of the fact that the scientific community has retracted the article from circulation. Again, the posting of a link

10 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4128611/

Figure 5: Example of a tweet regarding the retraction of article 2.4


Figure 6: Example of a tweet providing an alternative link to retracted article 2.4


does not indicate a high level of engagement with the content of the article; particularly so if the community does not engage with the scientific motivations for its retraction and elects instead to interpret the article's removal as being politically motivated.

The third observation is the use of 'broadcast' tweets in the case of mentions to Article 2.4. To illustrate: An anti-vaccination Twitter account will tag another anti-vaccination account by prefixing a (re)tweet with the Twitter handle of another member of the movement. The tweet may also include a call to action, a link or a hashtag (e.g. '#CDCwhistleblower'). Often the tagged anti-vaccination accounts will have a much larger number of Twitter followers and/or be more active on Twitter than the tweeter. In the example below (Figure 7), the tweeter had 2 888 followers while the tagged account @TannersDad had almost ten

Figure 7: Example of a tweet broadcasting article 2.4 to other Twitter accounts


times as many followers (21 400). And while the tagged accounts @ceestave and @NOWinAutism had numbers of followers similar to that of the tweeter, both accounts are highly active. The tweeter @MarcellaPiperTe had tweeted 13 200 times (since joining in June 2014), while @ceestave had tweeted 58 500 times (since May 2009) and @NOWinAustism 59 700 times (since August 2014). @TannersDad is also a highly active account with 222 000 tweets (since joining in October 2008).[11]

Article 2.5 was the only article in which a tweet was scored as being in the application category. The tweet in question was a retweet by the same account.[12] However, additional information was added to the tweet thread in the form of data published by the US Federal Drug Administration (FDA) as well as information from the journal article (including underlined text from the methods section). The first four comments comprise selected extracts the FDA on the presence of mercury in vaccines, for example, '#Flu #vaccine FLUZONE, p.18: Each 0.5 mL dose contains 25 mcg #mercury, 0.25 mL (infant) dose - 12.5 mcg mercury'. The fifth comment consists of scientific information

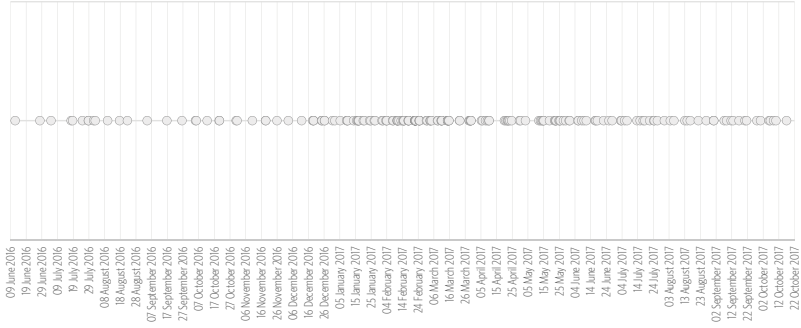
11 All followers and number of tweets as on 26 March 2018.

12 See the tweet in question at http://twitter.com/LotusOak/statuses/916317625407430657

extracted from the article: 'Found 7.6-FOLD Increased Risk of #AUTISM from Exposure to #Thimerosal'. It also includes an image of the results section of that article with the finding highlighted in red.[13] The tweet was deemed to indicate a level of interpretation consistent with being categorised on the 'application' end of the scale because it shows a degree of interpretation supported by content from the journal article.

Also of note is that of the tweets that mention article 2.5 in the random sample of anti-vaccination accounts, 55% (50 of 91) were retweets by the account @LotusOak. Figure 8 shows that @LotusOak tweets consistently from June 2016 to October 2017. These are not unique tweets; the majority of the tweets are retweets or reposts of the same tweet: '#STUDY: #Thimerosal-containing #Vaccines & #Autism Risk http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3878266/ … It's still in multi-dose vaccines'.[14] That @LotusOak retweets the same content verbatim is further evidence of a consistently low level of engagement on Twitter as far as this journal article is concerned.

Figure 8: Tweet frequency of @LotusOak to article 2.5 (n=197)



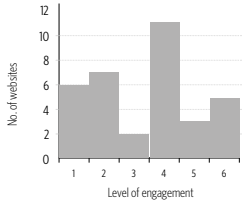

13 https://twitter.com/LotusOak/status/909814655044001794

14 https://twitter.com/LotusOak/statuses/832598920568111104

## Level of engagement on the web

The findings for level of engagement by the anti-vaccination movement with open access journal articles on the topic of autism and vaccination on web pages is shown in Figure 9. The figure shows a higher level of engagement compared to the levels of engagement on Twitter: 13 (38%) web pages fall into the access category, 13 (38%) fall into the appraisal category, and 8 (24%) fall into the application category. The relatively high number of web pages in both the appraisal and the application clusters differentiates the findings on the level of engagement on the web with those on Twitter.

Figure 9: Level of engagement with open access journal articles on the web (n=34)




Of the 14 unique websites that published the 34 web pages, 2 stand out as publishing web pages in which the authors of those pages engage closely with the content of an open access journal article: (1) Child Health Safety and (2) Vaccine Papers. Authors of articles published on these two anti-vaccination websites present findings in their own words, they reinterpret findings by engaging critically with the methods and/or analyses presented in the original study, often focusing on a scientific paper that shows no association between vaccination and autism, and they refer to other scientific research to support their reanalysis. An additional mark of their close engagement with the journal article is that the authors of these web pages reply to questions and challenges posed in the comments section of the web page, often posted by pro-vaccination individuals, in order to provide additional clarity in support of their reanalyses.

A comparison between the level of engagement of selected websites (that is, for those that contained more than three web pages in the sample) and the activity of their Twitter accounts shows that those websites that are the most engaged are also those with the lowest levels of activity on Twitter. This may suggest that members of the anti-vaccination movement select different online media as their preferred mode of communication depending on how closely they engage with scientific articles. Put differently, social media platforms such as Twitter may be selected by those in the anti-vaccination movement who do not wish or need to engage closely with the scientific content but who nevertheless seek to leverage science using the affordance of that online communication network to further their cause.

## Summary of findings

The findings show that the anti-vaccination movement constitutes a relatively small and variable proportion of the total number of social media accounts mentioning scientific articles on Twitter. For one group of open access journal articles, 11% to 18% of Twitter accounts were found to be anti-vaccination; in the case of a second group of open access journal articles, the proportion of anti-vaccination Twitter accounts was found to be between 1% and 3%. This indicates an interest in selected journal articles.

For those open access journal articles with a higher proportion of mentions from anti-vaccination accounts on Twitter, it was found that the activity (proportion of mentions) for those accounts exceeded their representation (proportion of unique anti-vaccination Twitter accounts). In other words, anti-vaccination Twitter accounts tweet more than their representation suggests. This indicates that the anti-vaccination movement 'punches above its weight' when a scientific article that in all likelihood supports its ideological position is accessible and fed into the flow of information in its social media networks.

Despite high levels of activity on Twitter, the level of engagement by the anti-vaccination movement with open access journal

articles is low. The frequent reposting of content and the relatively small proportion of original content is the main contributor to low levels of engagement on Twitter. In addition to frequent reposting, evidence was found of content being modified and blended to reignite levels of attention, if not engagement.

It was found that the low levels of engagement by the anti-vaccination movement with open access journal articles in the social media cannot be generalised to similarly low levels of engagement on the web. Overall, engagement by the anti-vaccination movement tends towards appraisal and application in the case of web pages. Two exceptional cases were found in which the authors of anti-vaccination web pages engage closely with open access journal articles. Findings also suggest that those highly engaged with scientific content on the web are relatively inactive in the social media.

## Discussion

### The production of uncertainty: Selective use of scientific information

In certain circumstances, being confronted by uncertainty has negligible consequences – decision-making can simply be deferred or suspended. But for the uncertain parent of a new-born child who faces a time-bound decision on whether to vaccinate, being confronted by anti-vaccination messaging seemingly supported by science, presents the very real possibility of the parent electing not to vaccinate. And this decision would be taken despite the fact that the consensus position within science, based on available scientific evidence, is supportive of vaccination:

> The broader public health implications of propagating these memes and articles make anti-vax activities more than a bizarre online curiosity. Most of the material that the […] accounts tweet are designed to erode confidence in vaccination. The goal is to make new parents question everything … Public health

> officials are concerned. […] [I]t is essential that when people go online for information they are left with the clear impression that vaccines are safe and effective.' If that's going to change, the people fighting misinformation need to understand how it gets spread in the first place. (DiResta & Lotan, 2015)

The findings on the number of mentions to specific articles indicate that the anti-vaccination movement is not only using scientific content in its online communications, but that it is selective in terms of the scientific content fed into their information flows.

The point to note here is that the information accessed is from journal articles produced early in the science communication process at a stage when truth claims are still contested and in flux. This finding confirms the observation that publics with a limited understanding of how science works – in particular, that science is iterative and self-correcting – may select and exaggerate the findings of individual studies (Kahan et al., 2017) and supports the large body of work in the science communication literature on 'phenomena of selection' (Akin & Landrum, 2017: 455). The anti-vaccination movement, rather than being made to wait for settled truth claims to emerge at the end of the iterative and progressive science communication continuum (Cloître & Shinn, 1985, in Bucchi, 2004), accesses 'unsettled', single-study truth claims, and interpret and share them as universal truth.

These 'scientific truths' hold value for the anti-vaccination movement because they confer legitimacy to its cause in the eyes of other non-scientific communication networks. According to Castells (1996), value is what the network determines it to be. In the case of the global anti-vaccination network, which could be situated within the larger global anti-establishment communication network, only that information that supports the beliefs of the network holds currency and is therefore worth exchanging. In the case of scientific information, the findings of this research show that those scientific articles that articulate a causal relationship between vaccinations and adverse health or that express doubt about the efficacy and safety of vaccines, gain currency in the

network. Conversely, scientific articles that disprove the dangers of vaccination hold no value and therefore do not circulate within the communication network of the anti-vaccination movement.

While the exchange of selected scientific information on the effects of vaccination serve to reinforce the belief systems of the anti-vaccination movement, they have the opposite effect on other networked communities who are both present in social media networks and therefore inevitably connected to the online anti-vaccination movement. The selective harvesting of information from open science and the communication of that information in social media networks, produces uncertainty in other online communities, even when there is consensus within the scientific community, as is the case for vaccine safety. The production of uncertainty can therefore be understood as an attack on the information flows of other networks and is aimed at destabilising certainty in the information that circulates in those networks.

## The amplification of uncertainty

In the theory on communication, amplification is the process of intensifying or attenuating signals during the transmission of information (Kasperson et al., 1988). The amplification of uncertainty using information from scientific sources takes place in the online communications of the anti-vaccination movement by means of at least two mechanisms that are supported by the findings of this study: (1) high levels of activity in online communication networks, and (2) low levels of engagement with scientific information in those networks.

### *High levels of activity*

In general, the most influential tweeters are more active than the less followed tweeters although it is not clear whether these individuals are widely followed due to their high posting volume, or whether they are prolific because their audience is sufficiently large (or appreciative) (Thelwall et al., 2013).

High levels of activity in the social media also increase the probability of content consistent with a particular stance appearing at the top of the content feeds of those who follow highly active accounts. Being listed at the top of content feeds, in turn, increases the chances of the content being shared with others in the social media network (Lerman & Hogg, 2014).

Kumar et al. (2018) have shown that highly active members in online communities are more likely to initiate interaction and conflict with other communities. However, 'while these interactions are initiated by the highly active users of the source community, the attackers and defenders who actually get mobilized to participate in the negative mobilization are much less active than them' (Kumar et al., 2018: 5). This suggests that those highly active anti-vaccination Twitter accounts are not only more likely to instigate interaction with the online pro-science community, but that they play an important role in mobilising less active members who, by taking up the cause, further proliferate the information flows of the anti-vaccination movement in the broader social media network.

The findings of this research show that the anti-vaccination movement 'punches above its weight' when a scientific article that supports its ideological position is accessible and inserted into its networked information flows on Twitter. In other words, the proportion of tweets by the anti-vaccination movement for selected open access journal articles is higher than the proportion of anti-vaccination Twitter accounts that mention the same open access journal article. It is the structure and affordances of networked communication that makes possible such 'network effects'.

The distribution of activity for the three most-mentioned articles show a skewed distribution in which most Twitter accounts mention an article only once. However, the data also show that for all three of these open access journal articles, there are a few Twitter accounts that mention the article more than 10 times, and in all three cases there is one Twitter account that mentions the article 100 or more times.

The most active Twitter account in the anti-vaccination movement was found to share the same content repeatedly across the network for an extended period of time. And, in general, most content consists of retweets and reposts. If we take as a starting point that the anti-vaccination movement in terms of its network properties is highly homogeneous, then research by Piedrahita et al. (2018) on how contagion dynamics emerge when networked actors repeatedly contribute to activity around a collective cause may be significant. They conclude that 'to the extent that digital technologies are inserting networks in every aspect of social life, our results suggest that we should expect to see more instances of large-scale coordination cascading from the bottom-up' (Piedrahita et al., 2018: 334). And according to Asur et al. (2011), rather than a large number of followers, the most effective strategy to propagate information (at least in terms of creating trending topics) on Twitter is to retweet; the number of retweets for a topic correlates strongly with the length of time the attention of the network is held.

### *Low levels of engagement*

The finding of low levels of engagement on Twitter, this suggests that scientific content is treated at face value, and that scientific information flows through social media networks with little need for actors in these communication networks to engage deeply with the information presented to them. This finding confirms findings by Thelwall et al. (2013) that the content of tweets linking to journal articles are unlikely to contain insightful responses to the content of those articles.

The explanation for face-value engagement, according to Stalder (2006), describing the work of Castells, is that certain networks rely and depend on information being taken at face value. Trusted intermediaries are established as central nodes in the communication network; they facilitate the rapid exchange and transfer of information that can be trusted at face value across the network.

Different programs of networks determine the speed at which information is accepted as accurate before it is acted upon. The

global science network, for example, is programmatically sceptical – scientists are more likely to interrogate information received from others in the network before acting. Social media networks are less so because they are programmatically a network of attention (Wu, 2016), and to retain attention, information must flow constantly regardless of the accuracy of the information. Neither ideologically-motivated social movements nor the owners of social media platforms, both of whom are locked into attention-seeking behaviour, derive value by adhering to the norms accepted within science as being necessary for establishing the truth.

The findings of this research support the proposition that scientific information is taken at face value in online communication networks. There is little evidence of engagement, enabled by affordances such as retweeting, and this allows information to flow at high speed between and across communication networks by enabling high levels of online communication activity.

In sum, a social movement that holds a view contrary to that of science (in this case, the anti-vaccination movement) is both highly active and selective in terms of the information accessed from open science and fed into its communications in the social media. The movement produces uncertainty in online communication networks; uncertainty that cascades across online communication networks programmed for attention and devoid of the normative guidance of science institutionalised for settling truth claims.

### *Risks and implications for science communication*

Risk can be amplified by social factors when risk signals are received, interpreted and passed on by a variety of social actors (Kasperson, et al., 1988). Previous research has interpreted social amplification effects as being place-bound (Petts & Niemeyer, 2004). However, if social amplification is dislocated from place and takes place in the space of flows exemplified by online social (media) networks, then the amplification of risk may be increased.

The amplification of risk in the social media (space of flows) has a bearing on how change is effected in the real world (space

of places). Miller (2017) argues that social media communication is not transformative but phatic and, as a consequence, the social media do not mobilise political action. The assumption is that change proceeds from the real-time, global interpersonal connections and communications in the space of flows made possible by the social media to action in the space of places against concentrated, hierarchically structured power such as an oppressive regime or Wall Street. In other words, change requires a switch from the space of flows to the space of places. Based on a review of the evidence, Miller (2017) argues that social media activism is not transformative or politically goal-orientated.

The evidence presented in this chapter suggests that the social media can effect change along different lines. Change is made possible by the production of uncertainty and, in certain spheres of social life such as health and well-being, is equally capable of driving change. Change proceeds from the real-time, global interpersonal connections and communications not to place-bound action but to an increase in influence over a diffused and interconnected mass public, more of whom seek meaning in the space of flows (Castells, 2009; Stalder, 2006). In this sense, every connected individual is a target in attacks on what is held to be certain. In cases where such attacks generate uncertainty, the potential arises to alter the decisions taken by individuals. In this change process, a shift from the space of flows to space of places is not required because change is effected by disrupting the flows of information in other communication networks through the creation of uncertainty. This includes disruption in the flows of scientific certainty.

It is unlikely that all change can be effected in this manner but it is short-sighted to suggest that the social media cannot be used by social movements to effect change, particularly when decision-making at the individual level poses risk to entire populations.

Unlike the global financial network that has created centrally located and trusted nodes in the networked flows of information to ensure that information in the network can be taken at face

value, as well as self-regulating structures within the network and the assurance of external, government intervention in the case of the threat of collapse, social media networks have no such mechanisms to ensure trust in the information exchanged.[15] This may account for why ideologically-motivated social movements active in global social media networks appear to borrow or import trust from the open communication networks of a social institution that is trusted by the public: science.[16] As the Vaccine Research Library proclaims: 'We have more than 7,000 links to abstracts and full text from mainstream, scientific literature […]. If their own literature isn't a 'reliable source', then what is?' (Vaccine Research Library, 2015: n.p.).

In the real world (the space of places), social cues confer authority and trust; in networks (the space of flows), these cues are not necessarily linked to class, cultural status or other traditional social cues (Lin, 2008). Network social capital or 'network capital' may present itself as a new type of capital to emerge alongside other types of social capital (Bourdieu, 1986) that accumulates in virtual networks as socially networked actors attract and consolidate the attention of others in the network.

Attention-seeking as a strategy to gain an influential position in networks accounts for the migration of unexpected actors to parts of the communication network where they are most likely to attract attention. Medical professionals and scientists are not immune to such attention-seeking behaviour in their quest to extend their influence over others, and it is for this reason that there are doctors and scientists to be counted in the online communication networks of the anti-vaccination movement. In some instances, existing capitals (cultural or symbolic) from the space of places may be leveraged to attract attention in the

15 It is not that the structures put in place by the global financial network are infallible. The point is that there have been attempts to self-correct, that is, to protect the network's program of surplus accumulation. There has been no concerted attempt to self-correct across social media networks.

16 See Schäfer (2017) on science as a trusted institution and Lin (2008) on open networks and the accumulation of social capital.

space of flows (networks) so as to accumulate network capital. For example, doctors converting their cultural capital (expertise) to network capital by switching allegiance from the professional network of medicine to that of the anti-vaccination movement's communication network.

There is also the potential for the conversion of network capital to economic capital. Fake photo sites on Twitter post doctored historical photos. The photographs posted are known to be fake but nevertheless hold popular appeal. Once these Twitter accounts have amassed a large number of followers, they leverage their network capital to attract economic capital as advertisers are prepared to provide financial rewards for the attention that these accounts can bring to their brands via their follower networks.[17] In other words, social media does not conform to expected rules and social hierarchies that confer authority or trust – a fake account can attract more attention and, by implication, yield more influence in a social media network than the account of a trusted, authoritative source, including that of a scientist.

The motivations behind scientists and medical professionals' participation in the social media or their motivations for expressing their allegiance to the anti-vaccination movement, may well be attention-seeking. Nevertheless, their presence and their inferred authority in these communication networks, destabilises traditional social cues of authority by creating the perception of divided positions on which there is, in reality, scientific consensus. In such a scenario, who to trust becomes unclear. It may be clearer to establish trust within relatively closed networks with shared norms and values (Burt, 2001), but to outsiders, where those norms are no longer shared, it becomes increasingly difficult to identify trusted sources. This has implications for uncertain parents and policy-makers alike who find themselves participating in online communication networks where trust has been destabilised, as this research has shown, by active minority

17 See Reply All podcast #48 by Gimlet: https://gimletmedia.com/episode/48-i-love-you-i-loathe-you/

groups exploiting the attention imperatives of those networks. As Southwell (2017: 223) states, communication of scientific information in the social media 'can undermine scientific authority, complicate decision-making and fuel the propagation of rumours and misinformation'.

At stake is the credibility of science as an institution in the eyes of the public (Kahan et al., 2017). Institutions such as science react to threats to their credibility (the extent to which they are trusted) by making taken-for-granted norms more explicit (Weingart, 2017). In network terms, the network's programmers must defend the logic of the network from attacks made by other networks or emanating from the network environment (Stalder, 2006). By making the institutional norms of science more explicit or by enforcing the terms of participation in the global science communication network, scientists should, in theory, refrain from non-normative attention-seeking in other communication networks or face sanction from their own.

How centrality is established in networks and how 'network capital' is accumulated to establish a position of trust and influence in an online social network, a question that was not explored in this chapter, remains opaque. If, as some have suggested (Muller, 2017), influence is a new form of power in the network society, then it becomes increasingly important to understand better not only who the trusted influencers are, but how they establish and protect their positions of influence.

This research has shown how the anti-vaccination movement is able to attract disproportionate levels of attention in online communication networks to exert influence over what is certain or true. Further research and conceptual development are needed to move towards a more comprehensive theory of attention, influence and power in the network society. Developing such an understanding will be critical for the science of science communication as it seeks to inform effective strategies for the communication of science to networked publics.

## Conclusion

The research presented in this chapter was a first attempt at creating a better, empirically-based understanding of new potentials in a changed science communication environment; specifically, the potentials arising from increased access by non-scientists to the formal communication of science.

The evidence presented points to the use of selected scientific information, extracted with little engagement from open access journal articles by a highly active minority group to produce and amplify uncertainty in the broader population using social media networks. The social media environment, devoid of scientific norms to steer action toward the establishment of truth, provides an ideal communication substrate, as does the networked nature on online communications. Online communication networks in the form of the social media enable relatively small social movements to exploit the affordances of those networks to amplify their messaging.

That the research focused on a non-scientific social movement opposed to vaccinations meant that the potentials identified were in the form of risks. The study of other social movements' use of the products of open science may reveal more positive potentials. Similarly, research on other social movements may confirm the findings of the single case presented in this chapter. Both endeavours are needed to be able to assert more generalisable insights to advance the science of science communication and to design effective strategies for the communication of science in society shaped by communication networks.

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