Covid-19 vaccine hesitancy on English-language *Twitter*

Mike Thelwall; **Kayvan Kousha**; **Saheeda Thelwall**

Mike Thelwall ✉
https://orcid.org/0000-0001-6065-205X

University of Wolverhampton
Statistical Cybermetrics Research Group
Wulfruna Street
Wolverhampton WV1 1LY, UK
m.thelwall@wlv.ac.uk

Kayvan Kousha
https://orcid.org/0000-0003-4827-971X

University of Wolverhampton
Statistical Cybermetrics Research Group
Wulfruna Street
Wolverhampton WV1 1LY, UK
k.kousha@wlv.ac.uk

Saheeda Thelwall
https://orcid.org/0000-0002-0333-399X

University of Wolverhampton
Faculty of Education Health & Wellbeing
Institute of Health
Wulfruna Street
Wolverhampton WV1 1LY, UK
s.thelwall@wlv.ac.uk

Abstract

Covid-19 vaccine hesitancy seems likely to increase mortality rates and delay the easing of social distancing restrictions. Online platforms with large audiences may influence vaccine hesitancy by spreading fear and misinformation that is avoided by the mainstream media. Understanding what types of vaccine hesitancy information is shared on the popular social web site *Twitter* may therefore help to design interventions to address misleading attitudes. This study applies content analysis to a random sample of 446 vaccine hesitant Covid-19 tweets in English posted between 10 March and 5 December 2020. The main themes discussed were conspiracies, vaccine development speed, and vaccine safety. Most (79%) of those tweeting refusal to take a vaccine expressed right-wing opinions, fear of a deep state, or conspiracy theories. A substantial minority of vaccine refusers (18%) mainly tweeted non-politically about other themes. The topics on *Twitter* reflect vaccine concerns, but those stating vaccine refusal in non-political contexts may unsettle the wider *Twitter* network by reaching outside right-wing areas of *Twitter*.

Keywords

Covid-19; Vaccination; Vaccine hesitancy; Vaccine refusers; Antivax; Antivaxxers; *Twitter*; Social media; Echo chambers; Misinformation; Misleading attitudes; Conspiracies; Fears.

1. Introduction

At the start of 2021, Covid-19 vaccination programmes are expected to reduce the circulation of the disease in society and help to control the pandemic. This is threatened by anti-vaccination ideas expressed by citizens reluctant to be vaccinated. Understanding how and where anti-vaccination information is shared may therefore help efforts to counteract it (**Wang** *et al.*, 2019). *Twitter* is used by a substantial minority of the population in some countries, including the USA (22% of adults: **Wojcik**; **Hughes**, 2019) and UK (possibly 43% according to *Statista*, 2020; see also: **Blank**, **Dutton**, & **Lefkowitz**, 2019), and so it is important to understand its impact on Covid-19 health information (**Rosenberg**; **Syed**; **Rezaie**, 2020), including for vaccine hesitancy. Whilst high profile misinformation may be banned or given a warning by *Twitter* and other social media sites (**Puri** *et al.*, 2020; **Roth**; **Pickles**, 2020), lower profile tweets remain and tweets about vaccine fears or hypotheses may also help to undermine public trust.

Vaccine hesitancy occurs when people refuse or delay one or all vaccinations for any reason (**Dubé** *et al.*, 2013). The *World Health Organization* (*WHO*) considered vaccine hesitancy to be one of the top ten risks to global health even before Covid-19, in 2019 (*WHO*, 2019). This de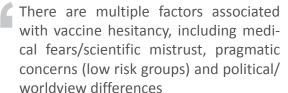finition encompasses the antivaxxers that oppose all vaccination and cautious people delaying their vaccination date; both are major public health issues for many diseases (**Dubé** *et al.*, 2013). For Covid-19, surveys with different sampling strategies and populations have found a substantial degree of vaccine hesitancy in 2020. These include 42% of US adults from an October 19 to November 1 *Gallup* panel survey (**Reinhart**, 2020), decreasing slightly to 39% by November 18-29 in a *Pew Research Center* panel, but with higher rates amongst Black adults (**Funk**; **Tyson**, 2020). In the UK in July, 16% reported being unlikely to take a vaccine (**Skinner**, 2020) and in September-October, 12% were strongly hesitant and 17% were unsure (**Freeman** *et al.*, 2020). In Italy, mistrust of vaccines increased during the early stages of Covid-19 (**Palamenghi** *et al.*, 2020). Concerns about vaccination pre-Covid were also common in China (**Wagner** *et al.*, 2020), and in May 2020 almost two thirds would prefer a domestic to a foreign vaccine (**Lin** *et al.*, 2020). A June 2020 survey of 19 countries in found vaccine hesitancy to vary from 45% (Russia) to 10% (China) (**Lazarus** *et al.*, 2021).

> The *World Health Organization* (*WHO*) considered vaccine hesitancy to be one of the top ten risks to global health even before Covid-19

Some reasons for vaccine hesitation and types of people that tend to be sceptical about vaccines are known, mostly for the USA. Republicans are more likely to refuse vaccines than Democrats, and to be anti-vaccine (**Reinhart**, 2020). Vaccine hesitators surveyed argued that Covid-19 vaccines had been rushed (37%) or mistrusted all vaccines (12%) (**Reinhart**, 2020). In the UK, Covid-19 vaccine hesitancy associated with excessive mistrust of the healthcare system (**Freeman** *et al.*, 2020). Confidence in the vaccine research process has been growing in the US, however (**Funk**; **Tyson**, 2020). Less educated and poorer people are more likely to reject a vaccine (**Funk**; **Tyson**, 2020). Internationally, vaccine hesitancy is associated with conspiracy theory beliefs, valuing personal freedom, or expressing disgust about blood/needles (**Hornsey**; **Harris**; **Fielding**, 2018). A December 2020 survey in North Carolina suggested some additional reasons (in free text comments) including trust in God for protection, likely vaccine ineffectiveness due to virus mutations, disbelief in the severity of Covid-19, fear of side effects, mistrust of Bill Gates and the mainstream media, and a perception of being an experimental subject (*ElonPoll*, 2020). Almost half of US republicans in an earlier poll believed that Bill Gates wanted to microchip them with Covid-19 vaccinations (**Romano**, 2020). Anti-vaxxers may subscribe to an alternative, non-scientific, worldview (**Browne**, 2018) that is resistant to formal scientific arguments. In the UK, vaccine refusal was more likely amongst people rejecting facemasks, or that were younger, unconcerned about Covid-19, more independent, and mistrustful of scientists (**Skinner**, 2020). In Israel, health staff and the public that were most at risk from Covid-19 were most willing to take a vaccine (**Dror** *et al.*, 2020). Populist politicians may also be undermining public trust in experts, reducing confidence in vaccination (**Kennedy**, 2019). Thus, there are multiple factors associated with vaccine hesitancy, including medical fears/scientific mistrust, pragmatic concerns (low risk groups) and political/worldview differences.

The primary goal of this study is to identify the main types of Covid-19 vaccine hesitancy information shared on *Twitter* in English to help health campaigns to address negative influences on the platform and understand how they spread. The secondary goal is to identify the main types of vaccine hesitant tweeter. This may shed additional light on the types of *Twitter* user that vaccine hesitant information is reaching. Although social media can be used to track public health issues (**Barros**; **Duggan**; **Rebholz-Schuhmann**, 2020) the purpose here is not primarily to identify vaccine concerns, since these have been revealed in previous surveys, but to describe the information shared on *Twitter* because of the risk that it is spreading hesitancy. Similarly, although this study is not about politics, vaccine hesitancy has political dimensions that will be explored when relevant.

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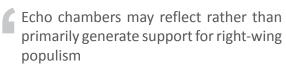
2. Background

Vaccination programmes provide substantial health benefits to populations by eradicating diseases like polio and smallpox and suppressing others, such as measles. There are international differences in strategies used in vaccination programs in developed nations, however, with mandatory vaccination in some. Children attending public (state) schools in all US states must be vaccinated, for example, but some states allow religious or philosophical exceptions (**Olive** *et al.*, 2018). Anti-vaccination sentiment also varies internationally and over time. In Italy, for example, anti-vaccination sentiment spread at least partly online 2009-14, leading to increased infection rates, but this was successfully combatted 2015-2018 by a political response that extended mandatory vaccination and sanctioned anti-vaccination doctors (**Signorelli**, 2019; see also: **Cuesta-Cambra**; **Martínez-Martínez**; **Niño-González**, 2019).

2.1. Echo chambers online

Vaccination is partly a political issue because it raises suspicions of state control from the libertarian right, feeding the anti-vaccination movement. Political polarisation can lead to echo chambers –people tending to connect mainly to others that they agree with–. When this happens, a person's information environment reinforces their beliefs because they are

rarely challenged by opposing perspectives. In the UK, 20% rarely or never see content that they disagree with on social media, and the percentage is even lower for those interested in politics or consuming multiple media (**Dubois**; **Blank**, 2018), so echo chambers may influence a minority in the UK. Although some have argued that the rise of right-wing populism in some countries is due to the echo chamber effect in social media, echo chambers may reflect rather than primarily generate support for right-wing populism (**Boulianne**; **Koc-Michalska**; **Bimber**, 2020).

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On *Twitter*, political issues tend to be shared between like-minded individuals, leading to echo chamber effects, but there is less polarization for other topics, such as non-political news or sports (**Barberá** *et al.*, 2015). Echo chambers help rumours spread on *Twitter* because users are connected to a likeminded network that is not isolated from the rest of *Twitter* (**Choi** *et al.*, 2020). The extent of political polarization on *Twitter* varies internationally, affecting the strength of echo chamber effects (**Matuszewski**; **Szabó**, 2019; **Urman**, 2020). Websites that are exclusively used by people from one political orientation (**Freelon**; **Marwick**; **Kreiss**, 2020; **Lima** *et al.*, 2018) may reduce the polarisation of more general sites, like *Twitter*, that are used by people from many political opinions (not necessarily reading each other's posts).
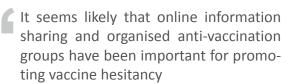
As a study of a measles outbreak in the USA showed, national responses to infectious diseases have a political dimension on *Twitter* (**Tang** *et al.*, 2018), presumably because the strategies are decided on by politicians. Anti-vaccination beliefs may therefore be helped by political echo chambers.

2.2. Anti-vaccination sentiment online from the news

The mainstream media seem to be strongly pro-vaccination, characterising anti-vaxxers as non-scientific and not credible (e.g., in Canada: **Capurro** *et al*., 2018), an opinion shared by many pro-vaccine citizens (e.g., in Australia: **Rozbroj**; **Lyons**; **Lucke**, 2019). Nevertheless, one counter-narrative story covered by the mass media, a scare about combined Measles, Mumps and Rubella (MMR) vaccination in the UK (**Begg** *et al.*, 1998) driven by a fraudulent and false published scientific study (retracted 12 years later), had devastating international consequences (**Deer**, 2011). Given the apparently almost universal pro-vaccination stance of the mainstream media, who may also be more cautious after the MMR scandal, it seems likely that online information sharing and organised anti-vaccination groups have been important for promoting vaccine hesitancy.

Before Covid-19, anti-vaccination information and opinions were widely shared online through social media sites and dedicated websites, partly driven by the news. An analysis of vaccine-related tweets from 2015 (60% from the USA) using English keywords found measles to be the main disease posted about. Discussion was apparently driven by news stories as well as grass roots organisations (**Radzikowski** *et al.*, 2016). Tweets about human papillomavirus (HPV) vaccines on *Twitter* in February 2015 were also driven by news stories, but some contained misinformation or concerns about the safety and effectiveness of the vaccine (**Chakraborty** *et al.*, 2017). News stories can influence public reactions to vaccines (**Cacciatore**; **Nowak**; **Evans**, 2018), and taking these stories seriously may be the reason for the increased rate of tweeting. Nevertheless, another study found pro-vaccination tweeting to increase during measles outbreaks in the USA covered by the news, but not anti-vaccination tweeting (**Deiner** *et al.*, 2019), and none of the 194 most retweeted tweets about vaccination after a 2015 diphtheria death in Spain were anti-vaccination (**Porat** *et al.*, 2019). Thus, the connection between news stories and vaccine tweeting is not straightforward.

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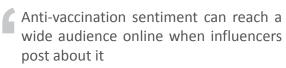
US vaccine sceptics are more likely to consume right-wing media sources. They are also likely to have been concerned by the MMR controversy (**Romer**; **Jamieson**, 2020).

2.3. Anti-vaccination sentiment on *Twitter*

Anti-vaccine sentiment has been widely expressed on *Twitter*. Vaccine opposition on *Twitter* in the USA increased by 80% during the first four months of Covid-19 (starting from February 15, 2020) compared to the four months before, with tweets increasingly mentioning vaccine ingredients, trials and federal health authorities (**Bonnevie** *et al.*, 2020). This study did not focus on Covid-19, which accounted for a quarter of the posts. In the USA, active anti-vaxxers on *Twitter* share three times as much misinformation as active pro-vaccination tweeters, with both sides frequently comparing Covid-19 campaigns to prior initiatives for other diseases (**Jamison** *et al.*, 2020).

A comparison of vaccine concerns tweeted by UK, Australian and Canadian users found similar worries in all countries, with concerned users likely to be connected to other worried users (**Shapiro** *et al.*, 2017). This study did not identify vaccine refusers, however. On Italian-language *Twitter*, vaccination 2018-2019 was discussed in a highly polarized context, with both pro-vaccination and anti-vaccination groups tending to be organised around this issue and primarily connected to their own community (**Cossard** *et al.*, 2020). A large-scale network analysis of vaccination on *Facebook* found that anti-vaccination clusters were smaller than pro-vaccination clusters but more likely to be connected to undecided users, and so could be effective at spreading vaccine hesitancy (**Johnson** *et al.*, 2020).

Within French language websites, there are interconnected communities of antivaxxers as well as those that argue against specific vaccines, some of whom hide their generic anti-vaccination agenda whereas others distance themselves from general anti-vaccination websites and enjoy a higher media profile (**Cafiero**; **Guille-Escuret**; **Ward**, 2021). In France, antivaxxers were connected to conspiracy theorists and alternative medicine advocates. Conspiracy theorists and proponents of (non-scientific) alternatives to vaccination are also active on *Facebook* (**Hoffman** *et al.*, 2019).

> **Anti-vaccination sentiment can reach a wide audience online when influencers post about it**

Anti-vaccination sentiment can reach a wide audience online when influencers post about it. This seems to have occurred in Samoa following a vaccine accident, for example, when non-medical influencers shared their opinions (**Hooper**, 2020). Influencers can build trust with their audience through regular online posting (**Reinikainen** *et al.*, 2020), so comments outside their area of expertise are potentially damaging.

One reason why health misinformation may spread online is that scare stories can be more interesting and easier to understand than accurate scientific information (**Wang** *et al.*, 2019). Since images help vaccine-related tweets to be shared (**Chen**; **Dredze**, 2018), tweets with scary anti-vaccination images (e.g., zombies) may have a higher chance of being retweeted. An analysis of vaccine-related comments on *The New York Times* website in 2015 found that pro-vaccination commenters often used strategies to debate the topic that might be ineffective, such as personal attacks against anti-vaxxers or appeals to scientific authority (**Gallagher**; **Lawrence**, 2020). Thus, when spread, anti-vaccination posts may not always be effectively challenged. For the vaccination debate, *Twitter* bots play a minor role, primarily through retweeting (**Yuan**; **Schuchard**; **Crooks**, 2019), and Russian trolls have also amplified the discussion during elections (**Broniatowski** *et al.*, 2018).

Another factor that may influence the discussion of anti-vaccination opinions online is the existence of mandatory vaccination programmes, since resisters may need to share information to develop strategies to bypass regulations. For example, vaccine scepticism was expressed in two large online parenting forums 2008-2012, with a common topic being methods to obtain exemptions from vaccine mandates (**Tangherlini** *et al.*, 2016). Opposition to vaccination was more common than vaccine support in 25 parenting blogs in 2016, often in opposition to vaccine mandates (**Meleo-Erwin** *et al.*, 2017).

For Covid-19, a content analysis of tweets mentioning 5G and the virus from a week up to 4 April 2020 found that a third were from conspiracy theory supporters (**Ahmed** *et al.*, 2020).

3. Methods

This study applied content analysis to a sample of Covid-19 tweets that expressed or discussed vaccine hesitancy. Content analysis involves multiple coders categorizing sets of texts into multiple relevant categories. It is one of the most common methods for investigating online health misinformation (**Wang** *et al.*, 2019). The second part of the study manually classified vaccine-hesitant tweeters according to the theme of their tweets.

3.1. Content analysis of vaccine hesitant tweets

A sample of vaccine hesitant tweets was obtained using a multi-stage approach (Figure 1). Instead of directly querying for tweets mentioning Covid-19 vaccine hesitancy, a general corpus of Covid-19 tweets was used, and vaccine-related tweets were extracted from it. This allowed a larger collection of tweets to be collected because the general Covid-19 tweets had been accumulating for eight months before the vaccine hesitancy study started and, at the time, tweets could not be collected retrospectively using the free *Twitter* API.

For the general Covid-19 tweets, the *Twitter* API (Applications Programming Interface) was polled for English-language Covid-19 tweets at the maximum permitted speed between March 10 and December 5, 2020 using four queries: coronavirus, "corona virus", covid-19, and covid19. The free software *Mozdeh* (*mozdeh.wlv.ac.uk*) was used for this. After removing duplicate and near duplicate tweets (duplicate except for hashtags or @usernames) and restricting each user to one tweet per month, selected at random (to reduce the influence of bots and prolific tweeters), this gave 19,977,683 English-language Covid-19 tweets.
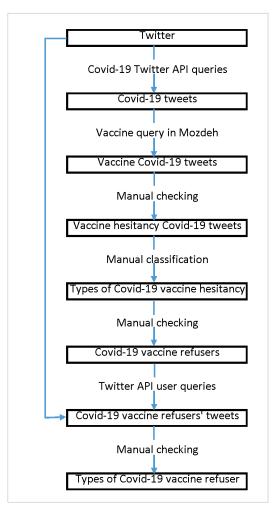

Figure 1. The main stages of the research design.

Vaccine-related tweets were selected from the Covid-19 tweets by saving those containing one of these words: vaccine, vaccines, vaccination, vaccinations, vaccinating, or vaccinated. This produced 429,482 tweets, which was 2.1% of the original set. Whilst vaccines were discussed steadily at a slowly increasing rate throughout the early

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stages of the pandemic (Figure 2), the volume of tweets increased dramatically with the 9 November *Pfizer* announcement of their Phase 3 efficacy test results (*Pfizer*, 2020). For comparison, only 1272 tweets (0.01%) mentioned the antivax movement (antivax, antivaxer, antivaxxer, antivaxx or antivaxxing). The vaccine tweets were arranged in random order using a random number generator and then the first author read the first 4000, identifying those discussing hesitancy about vaccines. This gave a list of 446 vaccine hesitancy Covid-19 tweets (Figure 1). According to their *Twitter* profiles, the 213 tweeters declaring their geographic location were mainly from the USA (62%), UK (15%), Canada (4%), Australia (3%), India (2%), and South Africa (2%).

For the primary analysis, inductive content analysis was applied to identify the common topics of vaccine hesitancy Covid-19 tweets. Content analysis is an appropriate method for identifying prevalence and when the types of class to be expected are to some extent known (**Neuendorf**, 2016). The relatively small sample of 446 vaccine hesitancy tweets out of 4,000 randomly selected Covid-19 vaccine tweets is large enough to identify major themes. Although a larger sample, such as 1,000 vaccine hesitancy tweets, would give finer-grained information, this would delay the research, and would therefore be undesirable because of its time-critical nature.

The procedure was as follows. The first author read the tweets, then designed a classification scheme and classified all the tweets with the scheme. A codebook was then created to define the classes, and the same tweets classified again. For an inter-coder classification check the second author classified the first 100 tweets with the codebook. After resolving disagreements, the codebook was revised for improved clarity and is available at:
https://doi.org/10.6084/m9.figshare.14185730

The first two authors then both reclassified all tweets with the revised codebook. The level of agreement was checked with Cohen's Kappa, giving 0.578 for the 346 tweets excluding the pilot 100 and 0.537 for all 446 tweets. These scores indicate moderate agreement (**Cohen**, 1960), which is enough to validate their use. The disagreements included tweets matching multiple classes, where the class was not explicit in the text so one coder had classified it as Other rather than inferring a class. The final classification for each tweet was reached after both coders examined all disagreements.

3.2. Categorization of vaccine refusing tweeters

For the secondary analysis of vaccine refusing tweeters, the vaccine hesitant tweets were categorized into vaccine refusers (tweeters stating that they would not take a Covid-19 vaccine), vaccine hesitators (expressing reservations about vaccination, delaying or refusing to take some Covid-19 vaccines), and others (not expressing an opinion or supporting vaccination). This produced 139 vaccine refusers. The tweets of these vaccine refusers were downloaded from *Twitter* with *Mozdeh* and each vaccine refuser classified by type from their tweets. During this classification five tweeters were removed because the context of their other tweets suggested that they were not vaccine refusers. A further 17
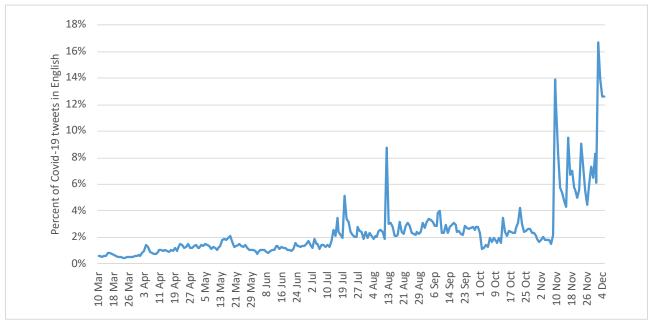

Figure 2. Daily percentages of Covid-19 tweets mentioning vaccine, vaccines, vaccination, vaccinations, vaccinating, or vaccinated.

accounts had been deleted by their owners or *Twitter* before they could be analysed, leaving 117 tweeters. These were classified by the first author scanning through their tweets for recurrent themes, identifying words that were more frequent in their tweets than tweets from other vaccine refusers (using the Word Association function in the *Mozdeh* software), and by searching (with *Mozdeh*) all tweets for the phrase "deep state", which was commonly used to indicate mistrust of state institutions in the USA from a right-wing perspective. This classification was performed by a single coder since there were too few to pilot test and assess for inter-coder consistency. Many classifications were straightforward due to a deep state mention in any tweet. Nevertheless, the results of this part are less robust than those of the first part.

> The three major vaccine hesitation topics on *Twitter* accounted for half (50.2%) of the 446 tweets manually categorised: conspiracies (23.5%), development speed (16.1%) and safety (10.5%)

4. Results

Most of the tweets with a user declaring a location (80%) were from the USA, UK and Canada. This should be remembered when examining the results.
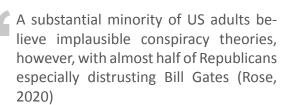
4.1. Tweeting about vaccine hesitation

The three major vaccine hesitation topics on *Twitter* accounted for half (50.2%) of the 446 tweets manually categorised: conspiracies (23.5%), development speed (16.1%) and safety (10.5%) (Table 1). Many tweets matched multiple topics, so the order of Table 1 is important because it reflects the category priorities. For example, a tweet was only categorised as discussing vaccine safety if it did not match any other class, although many jokes, conspiracies and Russian/Chinese tweets mentioned safety. The tweets were mostly from the USA, reflecting this national perspective. None of the Russian or Chinese vaccine tweets seemed to be from these two countries, instead commenting as an outsider about whether these two countries had been right to start vaccination programmes before completing and approving trials (this issue was also covered in the Western mainstream media). These tweets were expressing reluctance to take vaccines from these countries or suggesting that people in those countries should not take them.

Many of the conspiracy tweets argued that vaccines would contain microchips to monitor or control the population, they were a plot to depopulate the world, or that they were part of an unspecified secret Bill Gates plan. From a scientific perspective, most of these theories were extremely implausible. A substantial minority of US adults believe implausible conspiracy theories, however, with almost half of Republicans especially distrusting Bill Gates (**Rose**, 2020). Against a background of mainstream media sources accusing (then) political leaders like Donald Trump of lying and his accusation that the 2020 presidential election had been fraudulent, the least unlikely conspiracy theories were those accusing governments of lying about whether vaccines worked or were safe. This link is plausible because conspiracy theories are easier to believe when people are pre-disposed to them through prior beliefs (**Uscinski**; **Klofstad**; **Atkinson**, 2016).

Many of the tweets fearing that Black people were at risk from vaccines could have been classed as conspiracy-related. These seemed to be motivated by the infamous US federal government Tuskegee Syphilis study ending in 1972 that secretly experimented on poor African American men, with devastating consequences. This is widely known about through substantial press coverage and the award-winning film *Miss Evers' Boys,* leading to ongoing mistrust of researchers and doctors in the Black community (**Freimuth** et al., 2001). This mistrust apparently reduces the life expectancy of Black men in the USA by over a year (**Alsan**; **Wanamaker**, 2018), and seems likely to have an impact on Covid-19 mortality through vaccine refusals. One group of Black US doctors tweeted that vaccination was safe for Black people in response.

Tweets in the second most common category, development speed, typically expressed fears that vaccines had been rushed through the approval process and might therefore be unsafe because they had not been fully tested. In contrast to conspiracies, this is a more plausible concern given the faster than expected vaccine results. Scientists and governments have sought to explain why the vaccines could be developed quickly without compromising safety, in response to this concern. Tweets expressing fears about vaccine safety without giving a reason might have been triggered by the development speed or general resistance to vaccines. Some mentioned that the ingredients of vaccines sounded worrying, however.

> A substantial minority of US adults believe implausible conspiracy theories, however, with almost half of Republicans especially distrusting Bill Gates (Rose, 2020)

Tweets in the fourth most common class, efficacy, claimed that it was pointless to take the vaccine because its side-effects were like (mild) Covid-19 or that the tweeter was in a low risk category that did not need to be protected. These arguments do not consider the possibility that the tweeter might spread the virus to others in higher risk groups (e.g., parents). Some argued that virus mutations would render vaccines ineffective, which is plausible since vaccine escape mutations (VEMs) seem to exist for Hepatitis B (**Mokaya** et al., 2018), but, by the end of 2020, VEMs were not expected for Covid-19 (e.g., **Cohen**, 2020; **Lovett**, 2020).

Three classes (survey, survey results, persuasion) collectively included 12.1% of tweets and focused on whether people would take a Covid-19 vaccine. These all implicitly or explicitly regarded the issue of vaccine uptake as important. This reflects the high uptake required to achieve the level of (vaccine-based) herd immunity in society needed to supress the virus.

Surprisingly, a substantial minority of tweets were simple statements that the tweeter would not take a Covid-19 vaccine, without giving a reason. For example, one post merely stated four times that the tweeter would never take a Covid-19 vaccine.

Twenty of the tweets were jokes. Although humour cannot be interpreted at face value, it gives insights into personal fears. From the perspective of benign violation theory, humour arises from things that are threatening and non-threatening at the same time (**McGraw**; **Warren**, 2010). This generalises reversal theory, which argues that a joke must first increase physiological arousal and then decrease it (**Apter**, 1989). Vaccine-related jokes seemed to trigger vaccine-related fears, confirming that they are real in the population. For example, several jokes suggested that viruses would generate implausible side-effects, such as zombification.

Table 1. Tweets about vaccine hesitation (n=446) by type, as classified by two coders. Codes were applied in the order of priority listed in the table (e.g., jokes always classified as jokes).

Name and brief description of qualifying tweets	Tweets	
	n	%
Joke: Primarily attempts humour.	20	4.5
Black risks: Focuses on whether vaccines may be a threat/risk to Black people.	16	3.6
Survey/poll: Asks who will take a Covid-19 vaccine or links to questionnaire about Covid-19 vaccine hesitancy.	28	6.3
Survey results: Data from a survey about who will take a Covid-19 vaccine.	16	3.6
Russian vaccines: Mentions (concerns about) Russian vaccines.	20	4.5
Chinese vaccines: Mentions (concerns about) Chinese vaccines.	8	1.8
Development speed: For or against Covid-19 vaccines being unsafe because "rushed". Includes US states double checking nationally approved vaccines.	72	16.1
Efficacy: Argues that vaccines may not work (for the tweeter or generally).	37	8.3
No reason: Tweeter will not take the vaccine without explaining why.	25	5.6
Persuasion: Discusses importance of widespread agreement to vaccination.	10	2.2
Conspiracy: Argues that vaccination is a conspiracy. Includes accusations that vaccines are fake or governments lie about them.	105	23.5
Foetal tissue: Argues against vaccines developed with foetal tissue, for religious or ethical reasons.	11	2.5
Safety: Argues that vaccines could be dangerous, such as by modifying DNA, containing chemicals, or having side-effects.	47	10.5
Other: Anything else or unclear.	31	7.0

4.2. Covid-19 vaccine-refusing tweeters

Of the 117 vaccine hesitant tweeters, most (67) mentioned the deep state concept in at least one of their tweets and a further 12 tweeted general right-wing politics. A few focused on (Christian) religion (3), frequently tweeted anti-vaxxer sentiments (6), were anti-lockdown (3) or anti-abortion (1). Altogether, themes associated with right-wing politics accounted for 79% of the vaccine hesitant tweeters. Whilst Christianity isn't inherently political, Republican registered voters are likely to be Christian (79% vs. 52% for Democrats: **Gramlich**, 2020) and anti-vaccination sentiments are predominantly right-wing, so it therefore seems likely that the religious vaccine refusers were mainly right-wing.

Several tweeters (5) posted multiple times about anti-Black racism in the context of the USA or Africa, representing the only left-wing vaccine hesitancy theme for tweeters (4%). The remaining 18% of tweets were from tweeters with non-political themes, such as sport, music, news, or local events. For these accounts, the vaccine hesitant tweet did not fit the theme of the user but was a random statement of opposition to the vaccine. These people might agree with one of the groups above without tweeting about it (e.g., a right-wing sports fan never tweeting about politics) but the existence of such tweeters suggests that vaccine hesitancy on *Twitter* goes beyond the politically active and may therefore reach sport and other non-political spheres in *Twitter*. Whereas the right-wing tweets may be mainly broadcasting to an echo chamber and reinforcing vaccine hesitancy within that chamber, the remaining tweets disseminate vaccine hesitancy to a wider audience.

> ❝ 18% of tweets were from tweeters with non-political themes, such as sport, music, news, or local events ❞

5. Discussion

The results are restricted to the period analysed and are limited by a focus on the content of tweets rather than their readership size, reception or influence on *Twitter*. Some of the tweets may have been misinterpreted if they were sarcastic or contained in-jokes and some may have been political astroturfing or by bots (**Harris** *et al.*, 2014). The results are international, mixing different political contexts, although dominated (80%) by the USA, UK and Canada. Thus, the findings do not apply to all countries. Moreover, the sample size is relatively small (n=446) so the percentages in Table 1 are crude estimates of the prevalence of the issues listed. Finally, the resonance of the issues identified has not been assessed, for example in terms of retweets or Likes, because few tweets were manually classified, so the influence of the topics identified on *Twitter* is unclear.

The types of vaccine hesitancy tweet found (Table 1) are not surprising, given the discussion of most of the topics in the mainstream media or the reasons for vaccine hesitation given in recent surveys (*ElonPoll*, 2020). The right-wing slant for vaccine hesitation is also expected (**Romer**; **Jamieson**, 2020), as is mistrust of medical interventions from African Americans (**Freimuth** *et al.*, 2001; **Alsan**; **Wanamaker**, 2018). Some of the tweets do not reflect mainstream media topics, however. No US or UK mainstream

> ' The prevalence of conspiracy theories spread and challenged on *Twitter* is perhaps surprising '

media source seems to have treated the main vaccine conspiracy theories as credible, so *Twitter* may have been one of the platforms that helped spread it, perhaps helped by organised anti-vaxxer movements (**Cafiero**; **Guille-Escuret**; **Ward**, 2020), right-wing social media sites (**Heft** *et al.*, 2020) and even parenting forums (**Meleo-Erwin** *et al.*, 2017; **Tangherlini** *et al.*, 2016).

This study did not directly test for echo chamber effects but found a right-wing context for many of the tweets and tweeters, which could be within right-wing echo chambers amplifying anti-vaccination beliefs, including conspiracy theories. We did not distinguish between different forms of right-wing ideology, however, although seems likely that the libertarian right would be well represented. The examples of vaccine hesitancy expressed outside of echo chambers, such as in sports tweeters' timelines, confirming that anti-vaccination sentiment is not confined to echo chambers but can reach, and be promoted by, a wider public.

The prevalence of conspiracy theories spread and challenged on *Twitter* is perhaps surprising, although social media (particularly *Facebook* and *YouTube*) has been argued to be a site of Covid-19 conspiracy information (**Ahmed** *et al.*, 2020; **Wakabayashi**; **Alba**; **Tracy**, 2020; **Wakefield**, 2020). Whilst 44% of Republican voters believed in May 2020 that Bill Gates wants to secretly microchip them through Covid-19 vaccines (**Romano**, 2020), *Twitter* has a left-leaning bias, so a much smaller percentage of conspiracy tweets might have been expected. The relative prominence may be due to right wingers trolling or recruiting on *Twitter* or the bizarre nature of the conspiracy theories making them an interesting tweet topic. The choice of Bill Gates as the target follows a historical pattern of selecting rich philanthropists as hate figures, with Bill Gates apparently targeted for being well known, having spoken about the likelihood of a pandemic in a *TED* Talk, and funding Covid-19 vaccine development (**Wakabayashi**; **Alba**; **Tracy**, 2020).

Tweets criticising the pre-approval vaccination programmes in China and Russia seemed to originate from outside these countries. These tweets were presumably triggered by coverage in the Western media, together with explanations about why no Western country considered these two vaccines safe enough for systematic immunisation. Although there is no evidence for this in the tweets, these stories may have contributed to vaccine hesitancy by introducing the possibility that governments could make dangerous vaccination decisions. Western citizens opposing their own governing political party might then conclude that their politicians could do the same. When Western governments approved the *Pfizer* vaccine on different dates, they seemed to be mostly careful to avoid undermining each other's vaccination programmes by claiming that earlier approvals had been rushed, or publicly apologising afterwards for such suggestions (**Dewan**, 2020).

6. Conclusion

Covid-19 vaccine hesitancy on *Twitter* is primarily right-wing (79%, as mentioned above) and expressed through a combination of far-fetched conspiracy theories and more plausible concerns about development speed and safety. The posts reach beyond political *Twitter* to unrelated domains. This study has focused on the prevalence of different types of vaccine hesitancy on *Twitter*, and future research is needed to investigate how this information spreads between different users, as well as to explore different languages and social media platforms.

The results confirm that vaccine hesitancy is expressed on *Twitter* and show that it appears in many forms. The inclusion of conspiracy theories raises the possibility that they may spread partly through *Twitter.com*, and especially through right-wing accounts and among African Americans. Attempts to address vaccine hesitancy on *Twitter* might also need to address other types of concern, however, such as the safety of vaccines, especially given their fast production. Vaccine hesitancy should also be addressed in non-political parts of *Twitter*, since it appears in this context. This suggests, but does not prove, that vaccine hesitancy has spread on *Twitter* away from right-wing echo chambers, which would be a major concern.

> ' Vaccine hesitancy is expressed on *Twitter* and appears in many forms '

7. References

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