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COVID-19 vaccine deployment: Behaviour, ethics, misinformation and policy strategies

This rapid review of science of the behavioural aspects of vaccine uptake and misinformation is from the Royal Society and the British Academy to assist in the understanding of COVID-19.

This paper is a pre-print and has been subject to formal peer-review.

SUMMARY KEY POINTS

- A community-level vaccine coverage of 80+% will be required to protect the community from infection, dependent on the vaccine efficacy and duration of protection.
- Public expectations urgently need to be managed to prepare for a longer-term transition where non-pharmaceutical interventions remain in place.
- Behavioural factors underpinning vaccine uptake are: (1) complacency, (2) trust and confidence in efficacy and safety, (3) convenience, (4) sources of information; and, (5) socio-demographic variation.
- COVID-19 vaccine deployment faces an unprecedented degree of uncertainty and complexity, which is difficult to communicate, such as immune response, duration of immunity, repeated vaccination, transmission dynamics, microbiological and clinical characteristics and multiple vaccines.
- Priority groups for vaccine deployment need transparent public debate to build support for ethical principles.
- Current seasonal flu uptake is low in certain groups, suggesting vaccination challenges, which include: high risk groups under the age of 65 (40 - 50%), support staff in health care organisations (as low as 37%) and London and even variation amongst key workers such as Doctors (40 - 100%).
- Deployment and tracking should build on existing immunisation programmes such as primary care by GPs to identify comorbidities, track vaccinations and reminders for additional boosters.
- COVID-19 vaccine deployment faces an infodemic with misinformation often filling the knowledge void, characterised by: (1) distrust of science and selective use of expert authority, (2) distrust in pharmaceutical companies and government, (3) straightforward explanations, (4) use of emotion; and, (5) echo chambers.
- A narrow focus on misinformation disregards the fact that there are genuine knowledge voids, necessitating public dialogue about vaccine concerns and hesitancy rather than providing passive one-way communication strategies.

Executive summary

- Vaccinations are the most successful public health measure in history, saving millions of lives and preventing multiple diseases, with large societal and economic benefits.
- The percentage of the population requiring vaccination depends on efficacy (i.e., probability of preventing infection), reproduction number (R0), immunity, infectiousness and effectiveness of non-pharmaceutical interventions.
- If we assume an R0 value of around 2.5 - 3.0, a community-level vaccine coverage of 80+% for COVID-19 will be required.
- Public expectations must be urgently managed for a longer-term transition period where non-pharmaceutical interventions are still in place (i.e., face coverings, social distancing) even after first vaccines are available.
- The UK has high levels of immunisation for most major diseases, such as seasonal influenza (72%) and measles (93%), with immunisation uptake varying internationally and over time.
- Vaccine confidence (importance, safety, effectiveness) has increased over time with confidence damaged by late announcements of adverse risks or lack of clarity of content of vaccine or safety to certain groups (e.g., religion, children).
- Around 36% in the UK and 51% in the US report they are either uncertain or unlikely to be vaccinated against COVID-19.
- Five central behavioural factors underpin vaccine uptake: (1) complacency (perception of risk, severity of disease), (2) trust and confidence (efficacy, safety), (3) convenience (barriers, access), (4) sources of information; and, (5) socio-demographic characteristics (e.g., education, sex, ethnicity, religion, past vaccination behaviour).
- COVID-19 vaccine deployment faces high uncertainty and complexity over: immune responses following vaccination (e.g., fever), effectiveness, risks for various risk groups (children, older adults, pregnant women, chronic medical conditions, immunocompromised), duration of immunity, repeated vaccination, transmission dynamics, microbiological and clinical characteristics of the virus and multiple vaccines.
- COVID-19 infection and mortality has revealed structural inequalities by age, crowded settings, ethnicity, co-morbidities, sex, occupation and how these intersect.
- Deployment of a vaccine must follow ethical principles of priority groups to: (1) maximise benefit, (2) equality, (3) promote and reward instrumental value; (4) prioritise the vulnerable and potentially consider (5) economic consequences, and be publicly debated.
- Vaccine deployment faces an infodemic (information mixed with fear and rumour) with the rise of misinformation that fills knowledge voids under conditions of uncertainty.
- The anti-vaccination group is heterogeneous, with misinformation characterised by: (1) distrust of science and selective use of expert authority, (2) distrust in pharmaceutical companies and government, (3) simplistic explanations, (4) use of emotion and anecdotes to impact rational decision-making; and, (5) development of information bubbles and echo chambers.
- A narrow focus on misinformation and viewing individuals as easily influenced misses the fact that there are genuine knowledge voids about vaccines, urgent need for open dialogue and public engagement rather than providing passive one-way communications.
- Valuable lessons can be learned from history and international cases.

Conclusion and policy recommendations

- Transparent dialogue and community engagement with the general public about vaccine deployment must begin immediately, respecting emotions and real concerns, as opposed to a one-way information supply.
- Public expectation management is crucial and urgently needed to clarify that life will not immediately return to normal and non-pharmaceutical interventions will remain in place during a transition period, with clarity over the timing and scale of vaccination.
- Policies need to be coordinated and decentralised, with tool kits developed to support local authorities and aid with community engagement to support dialogue and reach diverse populations with tailored, appealing, visual and multi-language messages to mobilise local communities.
- Phased vaccine deployment could go beyond age- and comorbidity-based priority groups to adopt ethical principles related to equity beyond non-health high-risk occupations (e.g., teachers, bus drivers, retail workers) and priority to vulnerable groups (e.g., homeless, prisons).
- Seasonal flu vaccination is very high in the over 65 age group, suggesting that it will be an easier group to reach. However, there is lower uptake in certain groups which suggesting attention is required, including: under 65 and at risk (40 - 50%), support staff in health care organisations (as low as 37%) and in areas such as London. There is likewise variation amongst key workers such as Doctors where it is as low as 40% uptake to 100%.
- Vaccine deployment should build on existing immunisation programmes such as primary care by GPs on the weekend but also using GPs to identify comorbidities, log vaccinations and reminders for additional boosters or intensive vaccinations at polling stations. A model of centralised mass sites and roving teams are likely ineffective.
- The public needs to be empowered to spot and report misinformation, with more accountability for media companies to remove harmful information and legal consequences for individuals or groups that spread misinformation.
- There are strong commonalities across history, past pandemics and vaccine deployment; attention to history can avoid repeating common mistakes in vaccine deployment.

Contents

1. Introduction and motivation

Vaccination is a 'miracle of modern medicine'[1] and the most important contribution to public health in the past 100 years[2]. From 1796 when Jenner first introduced vaccination to protect against smallpox, vaccines have been developed to protect against pneumonia, measles, the human papillomavirus (HPV) and countless other infections. The value of vaccination has once again been emphasised with the outbreak of SARS-CoV-2 (hereafter COVID-19), with no scientific breakthrough ever more eagerly anticipated than this one. Considerable scientific resources and billions of pounds have been placed on producing an effective vaccine. Vaccination has been heralded as the solution to the current pandemic crisis, to reduce morbidity, mortality and transmission alongside non-pharmaceutical inventions. An assessment of return to investment found that every dollar invested in vaccines over a decade is estimated to result in a return of 16 times the cost[3].

Yet developing the vaccine is only one side of the challenge; it is vaccination not just the vaccine that saves lives, and ensuring that enough individuals are vaccinated is crucial[4]. A recent survey conducted in the UK found that around 36% of individuals are uncertain (27%) or very unlikely (9%) to be vaccinated against COVID-19[5]. In the US, 31% reported being uncertain with 20% stating they will not obtain a vaccine when it becomes available[6]. Vaccine take up during the recent 2009 - 2010 H1N1 pandemic was very low[7]. False beliefs over vaccines can lead to the reduction of vaccine uptake, which has led to the resurgence of diseases such as measles[8]. Vaccination for influenza in the UK for those 65 and older, however, has been stable and high at over 70% since 2005. As of 2019, in many nations between 90 - 95% of children are immunised for measles[9]. A recent report by the Royal Society's DELVE group examined the importance of determining the suitability of different vaccines, effectiveness and longevity of protection and levels of immunity required[10]. It also looked at the colossal challenge of manufacturing and prioritising recipients, the distribution and administration chain, need for global coordination and equal access.

The aim of this report is to extend our knowledge by focussing on the historical, ethical and socio-behavioural factors related to vaccine uptake, barriers to and suggestions for deployment. We draw on scientific evidence to aid policy makers in the UK and globally to plan effective and equitable vaccine deployment, with a focus on communication through dialogue and understanding rumours and misinformation. Given the global penetration of the COVID-19 pandemic, some estimate that up to 60 percent of the world's population needs to be vaccinated[11]. With vaccines soon to be deployed across the world, an understanding of how to ethically and equitably distribute them both within countries and globally, and develop policies and strategies for doing so is urgently required.

The current report extends our knowledge by first emphasising the public health and economic benefits of vaccinations. We then draw lessons from historical vaccination efforts, reasons for variation in immunisation coverage and vaccination hesitancy across countries and over time. The behavioural and socio-demographic factors underlying vaccine uptake are then reviewed. This is followed by a discussion of ethics and equity in vaccine allocation, considering ethical and equal allocation that also accounts for vulnerable populations. We then turn to the rise of misinformation, focussing on who produces the information, social networks and anatomy of the main strategies. The report concludes with concrete policy recommendations including the shift from communication to dialogue to fill knowledge voids, address public concerns and local community engagement.

2. Vaccinations save lives: Immunisation coverage and vaccine hesitancy

2.1. Vaccinations save lives and prevents disease

Vaccinations have been the most successful and far reaching public health measure in history, reducing disease and millions of deaths. The gains from vaccines in countering morbidity for multiple infectious diseases are staggering. In the last 18 years, the measles vaccination alone has been estimated to save more than 23 million lives[12]. Whereas at the start of the 20th Century, measles resulted in around 530,217 deaths per year in the United States alone, as of 2016 it decreased to just 69 deaths per year[4]. Although measles is a vaccine-preventable disease, in 2018 more than 140,000 people died worldwide from measles due to large outbreaks, with the majority of deaths of infants under 5 years of age in sub-Saharan Africa. Of those who survive, evidence shows that contracting measles can have long-term health effects which damage the immune system years after infection[12]. Vaccines have virtually eradicated many serious diseases beyond only measles such as mumps, rubella and pertussis (whooping cough). Before the vaccine for pertussis was introduced in the 1950s in England, over 2,000 people died in some years[13], which dropped to just one death in 2019[14]. Other vaccinations such as those for human papillomavirus (HPV) prevent a range of serious diseases such as cervical and mouth cancer. Cervical cancer is the most common cancer among young women 15 to 34 years old, with a considerable drop in HPV infections in England since the vaccination was introduced in 2008[15].

Vaccinations also have a considerable economic benefit. An economic evaluation in the US found that routine childhood vaccines for 13 preventable diseases in just one birth cohort year prevented 40,000 deaths and 20 million cases of disease, with net savings of $13.5 billion in direct and $68.8 billion in societal costs[16]. Another economic evaluation of 10 vaccines across 94 low- and middle-income countries demonstrated that the investment of $34 billion in immunisation resulted in savings of $586 billion to reduce the costs of illness and when taking into account broader economic benefits, the number rose to $586 billion[17].

Despite the immense benefits, it is often the case that negative and safety concerns receive considerably more attention. A simple search on MEDLINE from 1950 to October 2020 finds that 'vaccine risks' returns 37,751 records whereas 'vaccine benefits' delivers a mere 13,692 records. Yet vaccines are safer than many therapeutic medicines[18]. This focus on safety issues and examples can have detrimental effects, such as the re-emergence of diseases such as pertussis, measles and polio, discussed later in this report. The ironic aspect is that vaccinations have been so effective at eradicating serious diseases such as measles and polio, that the absence of these diseases brings a false sense of complacency.

2.2 Herd immunity thresholds

Effective disease prevention is contingent on achieved levels of vaccination compliance in populations. Vaccines provide not only protection for the individual who is vaccinated, but can also indirectly limit the spread of disease and protect the community. This means that vaccination not only has an individual benefit, but also acts as a protective shield for vulnerable community members. If sufficient numbers are vaccinated and immune for a period post immunisation, the chain of infection can be broken within the population such that the basic reproductive number R0 falls below unity in value (R0<1) 'herd immunity' is achieved[4]. As a rough approximation, the level of herd immunity as a proportion of the population p required to block transmission is given by p>[1-1/R0]/f, where f is vaccine efficacy as a proportion. If the duration of immunity is short, a more complex relation exists[19]. Although other approaches have been suggested to achieve herd immunity by allowing COVID-19 to spread widely in the population, vaccines are the safest way to reach the target level. The percentage of the population that needs to be covered by vaccination depends on vaccine efficacy (i.e., probability of preventing infection), the natural reproduction number of the infection (R0), the proportion of the population already exposed before vaccination deployment, infectiousness of asymptomatic individuals, and the effectiveness of parallel interventions (e.g., non-pharmaceutical interventions)[20]. As noted in a previous SET-C review, it is possible to estimate how many individuals the typical transmitter is capable of infecting (if all were susceptible) using the R0, the basic reproduction number[21].

For COVID-19, if we assume an R0 value in the UK of around 2.5 - 3.0, a community-level vaccine coverage of around 80+% will be required to protect the community from infection, which also depends on the efficacy of the vaccine and the duration of protection (which will influence the frequency of vaccination). Simple calculations suggest that for an R0 of 3.5, a vaccine with an efficacy of 80% would require 90%+ vaccination coverage with a vaccine providing long term immunity (many years) required, to eliminate viral transmission. This level of coverage must be uniform across the UK to avoid creating pockets of susceptibility.

Our understanding of longer term immunity is limited at present. Herd immunity, as judged by serological surveys, is currently heterogeneous across the UK. A serological survey of London estimated that around 18% of the population had antibodies, with other surveys reporting substantially lower levels[22]. Seroprevalence surveys that measure antibodies are often used to estimate how many people in a population have been infected by COVID-19, with the assumption that they will carry some degree of immunity. A recent pre-print on medRxiv finds that naturally acquired antibodies may drop after 2 - 3 months, which has consequences for re-infection and vaccination[23]. A recent genomic study published October 12 2020 demonstrated a risk of re-infection, with the second infection more severe than the first[24]. Work examining memory T cells suggests that not only antibodies that play a role. T cells may offer some pre-existing immunological response and thus impact the severity of the disease and future infection[25]. This was the case for H1N1, for instance, where those with pre-existing reactive T cells had a less severe disease[26].

2.3 Immunisation coverage for existing diseases: A cross-national comparison

For a general indication of the extent of immunisation in the UK in comparison to other countries and over time, Figure 1 shows the percentage of individuals in the population 65 years of age and older who were vaccinated for seasonal influenza (top panel) and percentage of children immunised for measles (bottom panel) from 2000 to 2019 (see Appendix 1 for Diphtheria, Tetanus and Pertussis and Hepatitis B). For influenza, we see considerable variation across countries. Hungary has low levels, similar to some Eastern European neighbours[9]. Levels in the UK and US remained relatively high and stable at around 70%,

with South Korea's vaccination uptake gaining over time. In contrast, countries such as Italy, France and Germany experienced a drop in uptake, particularly after 2014.

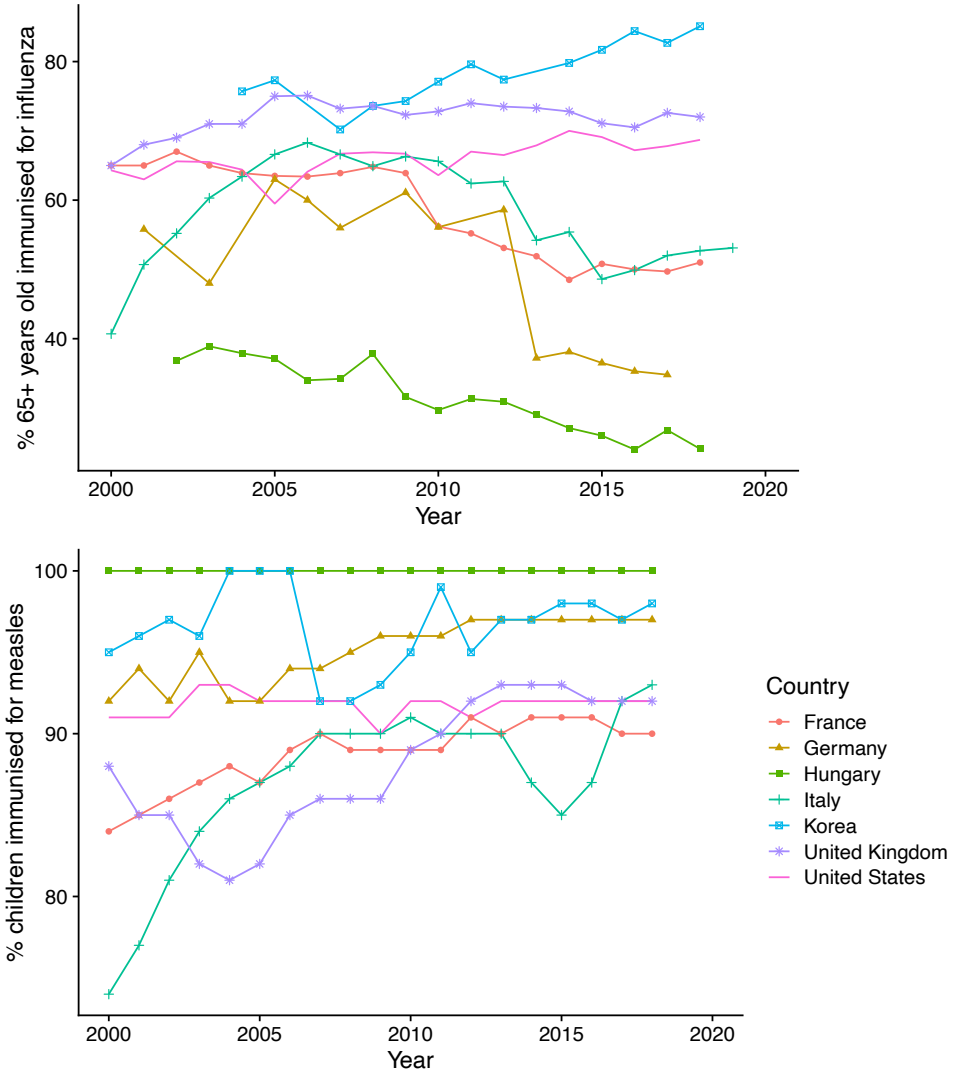
Vaccination levels for measles are likewise mixed, with countries such as the UK, France and particularly Italy making large gains in coverage over the last two decades. Vaccination levels were very low in Italy the early 2000s. This resulted in a serious measles outbreak resulting in the introduction of compulsory vaccinations in Italy in 2017 to deal with the surge of the disease, which later included even more stringent measures such as banning unvaccinated children from school[27]. Appendix 1 shows very low levels of DTP and Hepatitis B in France which rose appreciably over time. Some attributed the low levels in France to public dissonance in reaction against what was perceived as alarmist vaccination campaigns by public health officials, which we return to in our policy recommendations[28].

2.4 Vaccine hesitancy: A cross-national comparison

Despite the fact that vaccines represent one of the greatest public health achievements in the past century, a growing body of research has examined vaccine confidence or hesitancy, which refers to delay in acceptance or refusal despite availablity[29,30]. Vaccine hesitancy has been largely attributed to: confidence, complacency and convenience, as described shortly[30]. There is considerable research that has focussed on detecting, monitoring and analysing public confidence in vaccines, including systematic reviews[29], surveys[31] and related policy reports such as from the WHO SAGE working group on vaccination[30]. A considerable share of the contemporary literature on vaccine hesitancy focuses on parental attitudes regarding childhood vaccination, largely surrounding MMR and HPV[32]. Other areas concentrate on certain risk groups such as pregnant women[33] or Asian populations disproportionately affected by certain viruses such as the Hepatitis B Virus (HBV)[34].

FIGURE 1.

Percentage of influenza vaccinations in the population aged 65 years and older (top) and percentage children immunised for measles (bottom), selected countries, 2000 - 2019



Source: OECD (2020)[9]

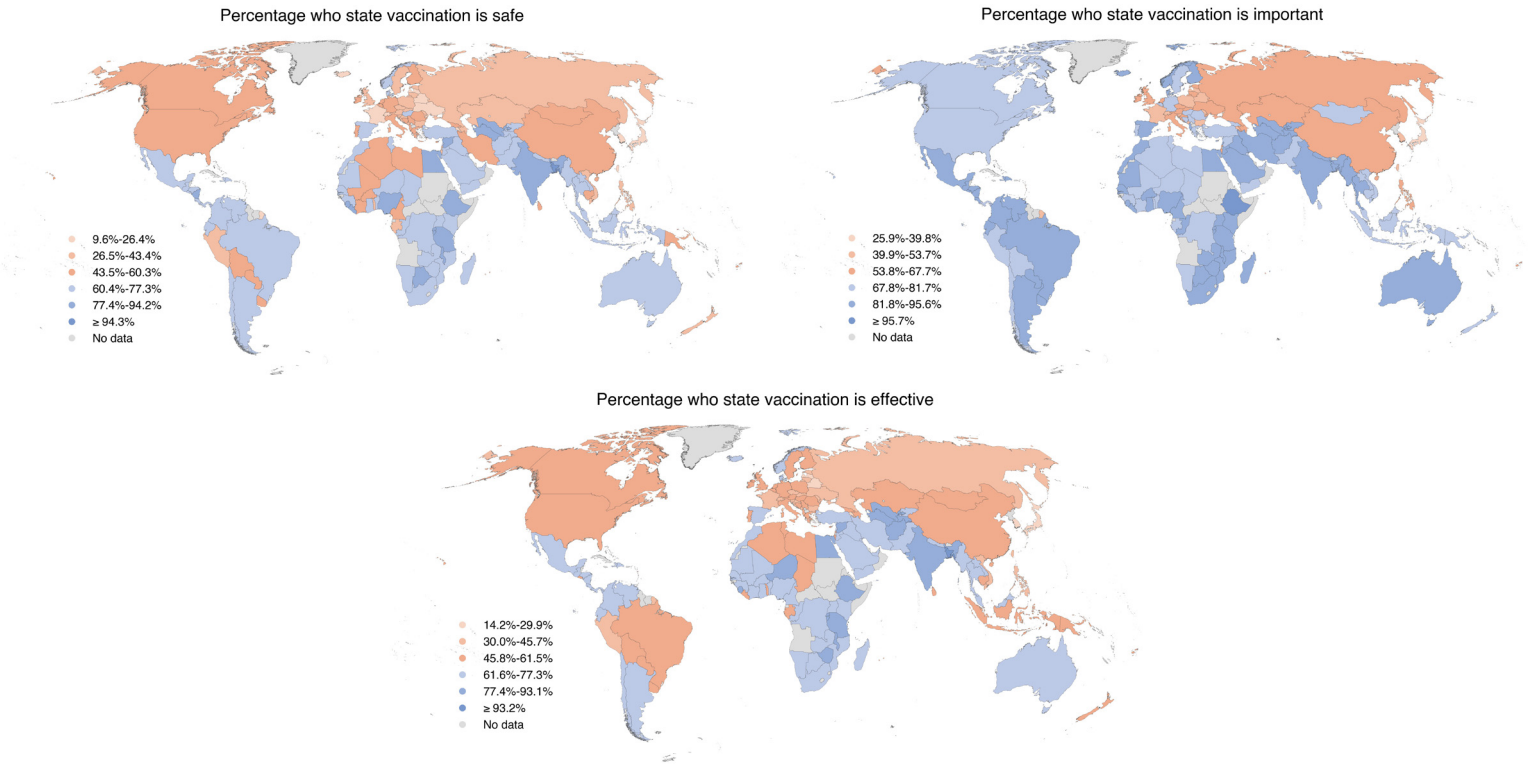
A recent study published in the *Lancet* from the Vaccine Confidence Project led by Larson examined vaccine confidence across 149 countries between 2015 and 2019[31]. The authors found that confidence in the importance, safety and effectiveness of vaccines fell across certain areas of the world (e.g., Indonesia, the Philippines, Afghanistan, Pakistan, South Korea). They also revealed significant increases in respondents who strongly disagreed that vaccines are safe in certain countries (e.g., as above but also Nigeria, Siberia).

Widely published safety scares can have deep, long-lasting influence on vaccine confidence. The authors attributed the drop in vaccine confidence in nations such as the Philippines and Indonesia to the announcement of the vaccine manufacturer in 2017 that the newly introduced dengue vaccine (Dengvaxia) posed a risk to those who had not previously been exposed to the virus. This resulted in outrage and panic, where almost a million children had already been vaccinated the previous year. This suggests that widely rolling out a vaccine which may be followed by announcements of adverse risks can damage confidence. Japan ranked the lowest in confidence likely due to the human papillomavirus (HPV) safety controversy following the government decision to stop proactively recommending HPV vaccination in 2013. The fall in HPV uptake was staggering from 68 - 74% in the 1994-98 birth cohort to just 0 - 6% for those born in 2000[35]. A similar drop was found in Indonesia when senior Muslim leaders warned against vaccination, resulting in a sharp drop[31,36].

Conversely, confidence improved in many European member states such as Italy, France and Ireland. In Figure 2 we use data from the recent *Lancet* study[31] to map the percentage of respondents who strongly agree that vaccines are safe, effective and important in 2018 for a global comparison. Here we see low confidence in the safety of vaccines in France and some Baltic (Estonia, Latvia, Lithuania) and Eastern European countries such as Poland. The UK also shows relatively lower levels of confidence in safety of vaccines compared to many African, Asian and South American countries. The middle panel illustrates those who strongly agree that vaccines are effective, mirroring roughly the same attitudes for vaccine safety. In the bottom panel, however, we see considerably higher global consensus that vaccines are important, with lower levels in countries in Europe (including the UK, France, the Netherlands, Italy), Russia, China and the Philippines.

FIGURE 2.

Percentage who strongly agree vaccinations are safe, effective, important, 2018



Source: Figure made using raw data from de Figueiredo *et al.* (2020)[31]

3. Behavioural and socio-demographic factors underlying vaccine uptake

Behavioural and socio-demographic factors are key drivers of both vaccination intentions and uptake. This section provides a brief overview of the main factors with study exemplars.

3.1 Complacency and threat appraisal

Perception of personal risk. A persistent finding is that individuals are complacent and perceive that if they are at a low or no risk of contracting, becoming ill or dying from the virus, there will be little reason to vaccinate. As described shortly, the individual risk of dying from COVID-19 has been disproportionality concentrated in older ages, those with co-morbidities and particularly ethnic groups. A study in March 2020 in the US during the initial outbreak of COVID-19 found that 25% were very worried about contracting the virus with around 13% not worried at all. Those who rated the virus as less serious were younger individuals, men, those living in lower socio-economic circumstances and Black participants[37]. In August 2020, however, the Director of the WHO recognised what has been termed 'long COVID', which includes debilitating symptoms such as breathlessness and fatigue for those who have recovered, predominantly concentrated in younger age groups[38]. The growing awareness of these long term health risks may increase awareness of personal risks.

Multiple studies of H1N1 vaccine uptake amongst health professionals found that those who perceived that they were not at risk were less likely to be vaccinated[39]. Conversely, a study of pregnant women in the US found that those more worried about the virus had a higher likelihood to be vaccinated[33]. A study of H1N1 in the UK found that one of the strongest predictors of intentions not to vaccinate was the reason: "I cannot be bothered"[40]. This suggests that considerable effort may be required to convince certain groups of their own risks and of the low barrier to vaccination.

Perception of severity of pandemic or disease. Particularly relevant for COVID-19 are individual's perceptions regarding the threat or severity of the disease or pandemic. As with COVID-19, previous pandemics were initially met with scepticism and the belief that the virus was akin the seasonal flu. Numerous studies of H1N1 found that when the public believed it was a mild disease they had lower intentions to be vaccinated[41,42].

3.2 Trust: Efficacy and safety under conditions of uncertainty

3.2.1 Efficacy under conditions of uncertainty

The strongest predictors of intention and behaviour related to vaccination is that the individuals need to understand and also believe that it is safe and effective. Studies with individuals in South Korea[43] and the UK in relation to H1N1 found that when individuals believed that the vaccine was effective, they were more likely to be vaccinated.[40]

What is unusual for COVID-19 compared to previous vaccines is that dialogue and communications about the safety and efficacy of the various vaccines must be developed under conditions of uncertainty. According to a COVID-19 Clinical trial tracker, over 100 vaccine candidates are currently active[44]. As described in the recent DELVE report, vaccines must go through various trials, with none of the current vaccines in the final stage of Phase III trials. It is at this stage where the vaccine is tested for potential side-effects across various types of people. At the time of writing, there is still lack of clarity about the efficacy of different vaccines. Additional certainty is required regarding the length of protection and vaccination schedules or need for boosters[10]. Generally when vaccines are introduced and communicated to the public there is already detailed information on immune responses following vaccination (e.g., fever), effectiveness, risks for various risk groups (children, older adults, pregnant women, chronical medical conditions, immunocompromised), and also on the duration of immunity and the need for repeated vaccination. Vaccines are overwhelmingly safe, but do have some side effects for particular individuals.

3.2.2 Safety and speed of vaccine development and political interventions

A large volume of research lists fears of safety as one of the largest deterrents of vaccine uptake[29]. Multiple media reports and individual scientists have discussed the speed at which the COVID-19 vaccine has been developed and tested, raising safety concerns[45,46]. The timeline for vaccine development for COVID-19 is unparalleled, with vaccine development which normally takes a decade compressed into 1 to 2 years[47]. As discussed in the recent DELVE report, vaccine candidates must complete clinical trials, be licensed by regulatory boards and develop complex manufacturing and distribution programmes[10]. Although regulatory bodies have in the past taken between one to two years, the UK Medicines and Healthcare products Regulatory Agency (MHRA) has reported that it will fast-track it to take 70 days.

Some experts warn that vaccine development during COVID-19 has also become entwined with political timetables, which they allege may jeopardise safety and efficacy. A prominent example is 'Operation Warp Speed' in the US, for instance, which aims to have the vaccine ready before the presidential election in early November 2020[45]. Experts point to some cautionary examples where the speed of vaccine deployment or development impacted safety, such as the 1955 Cutter incident discussed later in this report[48]. In 1976, when President Gerald Ford faced an election in the US, a vaccine for a swine flu strain was fast-tracked and given to 45 million Americans in fear of an impending epidemic[49]. Of those who were vaccinated, 450 individuals developed Guillain-Barré syndrome and there were 30 deaths. Although not exhaustive, the key lessons learned were that when large numbers of people are exposed to a vaccine, adverse reactions emerge and children respond differently. It was also noted that public explanation was necessary when coincidental deaths occurred that were unrelated to the vaccine and what the relationship was with new and unrelated disease (Legionnaires) that emerged.

Another example is the Pandemrix vaccine used during the 2009 - 10 H1N1 (swine flu) epidemic, which had been allegedly given rapid approval by the European Medical Association (EMA)[50]. In the UK it was administered to six million high-risk groups including children. It is estimated that of around the 30 million that were vaccinated in Europe around 1,300 children and adolescents developed narcolepsy, which was likely to be causal[51]. Recent attempts to eradicate polio in Africa, for instance, are referred to where mass production began while the vaccine was still in clinical trials with the aim to also faced serious setbacks in 2019 when the live-virus vaccine was found to cause new infections[52]. Across 12 countries, 196 children were paralysed by a strain derived from a live vaccine (vaccine-derived polio virus type 2) that in turn regained virulence and spread.

These rapid approvals do not necessarily denote lower quality or vigilance but rather follow similar approval procedures. This happened for instance during the 2014 - 16 West Ebola outbreak which had both high transmission and case fatality rates. In that case, the risk of receiving an experimental drug was deemed manageable and was lower than the risks implicated by contracting the virus. Other examples are in 2019, where mass production began for vaccine for a new polio outbreak while the vaccine was still in clinical trials, with plans to deploy it for emergency use[52].

3.2.3 Distrust and underrepresentation of key risk groups in vaccine trials

There has also been the concern that COVID-19 clinical trials have underrepresented certain groups. One concern is the lack of representation by minority groups, particularly by race and ethnicity[53], yet these groups have the highest rates of hospitalisation and mortality from the virus. This is often related to high levels of distrust amongst certain groups. In the US for instance, the government's Tuskegee syphilis study from 1932 –72 carries a lasting negative memory[54]. In this experiment, African Americans who had the disease were told they were provided free health care and then intentionally not provided treatment and were not informed in order to study the progression of the disease. There are also age-based concerns about the trials. Although the vaccine will very likely be targeted first to those aged 65 and older, the trials largely contain younger age groups but also exclude children.

3.3 Convenience and Planning: Physical barriers and building on existing structures

A well-planned distribution chain, convenience and building on successful vaccination structures has been found as crucial for vaccination uptake. Convenience of vaccination has been found in numerous studies as pivotal, including broad office hours, easy to reach by public transportation and attention to the financial and time costs it would take some individuals to receive the vaccination or take off work. Physician's offices were the dominant location of H1N1 vaccinations, particularly among minorities. The CDC in the US noted that vaccination levels were particularly high for H1N1 for children in states where vaccinations took place at schools[55]. Given that vaccination levels for influenza and childhood vaccination are high in the UK, it is logical to build on those existing and trusted infrastructures, including pharmacies. Deterrents for vaccination were the need to bring an immunisation card, a complicated or unclear vaccination schedule, or poor communication. Some studies also mentioned concerns about the reliability of distribution and supply, also highlighted in the recent DELVE report[10], and is a major hurdle in terms of late timing of vaccine delivery during H1N1[55].

3.4 Sources of information and knowledge deficits

In the last section of this report we provide a more detailed examination of information gaps and misinformation. Sources of information are another factor related to vaccine uptake. A study of parents during the H1N1 pandemic found that those who were more likely to vaccinate their children watched the national television news and pro-actively engaged in information-seeking behaviour[56]. Another study in the US found that individuals who received their information about H1N1 from a health-care provider or public health department were more likely to perceive the vaccine as safe[57]. A Greek study concluded that those who received information from the government were more likely to be vaccinated than those who primarily received information from the television and radio[58]. Effective communication and vaccine distribution strategies has been suggested as particularly vital for minority communities[59].

As we discuss in more detail shortly, a growing strand of literature claims that internet users are more likely to believe that healthy individuals do not need to be vaccinated and that it is harmful[60]. An experimental study examined the impact of exposure to anti-vaccine conspiracy beliefs, a group exposed to refuting anti-vaccine conspiracy theories and a control group on vaccination intentions[61]. They found that those exposed to anti-vaccine beliefs showed a lower intention to have a vaccination compared to the supporting and control group, with the effect mediated by the perceived dangers of vaccines, perceptions of powerlessness and disillusionment and mistrust in authorities. This provides some evidence that exposure to anti-vaccine conspiracy theories can shape vaccine uptake and health behaviours.

3.5 Socio-demographic characteristics related to vaccine uptake

A wealth of studies and systematic reviews isolated key socio-demographic characteristics related to vaccine hesitancy, and factors predicting vaccine intentions and uptake. It is notable that findings can be heterogeneous, related to whether the vaccination is for children or adults, with variation across countries and across whether survey participants were health care professionals or members of the general public.

Education and socio-economic status. Findings are mixed in relation to the educational levels related to vaccine hesitancy with many studies finding that hesitancy is reduced with higher levels of education[29]. Online searches are said to have a stronger impact on the biases of college-educated mothers than newspaper coverage, with exposure to negative information strengthening their bias via the mechanism of confirmation bias[62]. Closely related to education is socio-economic status with those having lower incomes or the unemployed holding less positive views of vaccines[29].

Age. Given that the majority of literature is on childhood vaccination, the impact of age varies according to whether it is a vaccine aimed at children or adults[63]. Age patterns generally show that younger people are less likely be vaccine hesitant, particularly in relation to vaccinations for children and young adults[29]. The seasonal influenza and pandemic vaccination literature shows the opposite effect of more intentions and vaccinations by the older population. Given that recent pandemics (such as H1N1) and seasonal influenza are more detrimental to the older population[64], these differences are logical. A systematic review of H1N1 vaccination uptake found that those who had higher intentions for vaccination were likely to be older, related to the age-related risks of that virus[42].

Sex and parental status. Men are more likely to hold anti-vaccine sentiments than women[29], which is striking given that many of the anti-vaccine MMR parental activists and online forums are populated by women. Given that the majority of the literature has focussed on children's vaccinations and parental attitudes, studies often report mother's attitudes and behaviour as opposed to parents in general[62]. Studies of H1N1 found, however, that men had higher intentions of vaccination than women[42]. Jennifer Reich who studied vaccination hesitancy of parents in relation to measles explores what defines good parenting in relation to vaccination[32]. She notes that relatively few parents actually reject vaccines, but moreover harbour concerns surrounding children's safety and the pain of injections, suggesting the need for dialogue and communication in order to understand these concerns.

Ethnicity. Ethnic minorities have been shown to have lower levels of vaccination, often related to issues of trust in the government or health care system, discussed previously, but also lack of health care insurance and convenience. A systematic review of H1N1 vaccination intentions and behaviour, however, found that in the UK, US and Australia, individuals from ethnic minorities were more likely be vaccinated[42]. This was attributed to the fact that particularly individuals from Asian ethnic minorities were more likely to be hospitalised in the UK[65]. But also that for British children, the H1N1 mortality rates were higher for Bangladeshi and Pakistani children, raising awareness in those communities[66]. A study of the H1N1 and seasonal influenza uptake in the United States found a disparity in vaccine uptake of 13.8% for Blacks versus 20.4% in the White and Hispanic groups[59].

Religion. Clarity of messaging surrounding the safety of the vaccines should also be sensitive and address concerns across religious and cultural groups. The drop in confidence of vaccines in Indonesia has been partially linked to key Muslim leaders questioning the safety of the MMR vaccine who issued a fatwa (religious ruling) that the vaccine was haram (containing ingredients derived from pigs, thus unacceptable for Muslims)[36]. A predominantly Muslim sample of respondents in Malaysia reported concerns that the vaccine was not a Halal vaccine and were thereby less likely to be vaccinated.[67]

Social network. The proportion for and against vaccination within an individual's' social circle has also been shown to be relevant. Parents who chose not to vaccinate their children had a much higher percentage of individuals (70%) in their social networks with similar attitudes than those who did vaccinate their children (13%)[60].

Past health and vaccination behaviour. A systematic review of H1N1 vaccination uptake found that one of the strongest predictors for vaccination was past behaviour. Those who had previously been vaccinated against seasonal influenza were the most likely to opt for an pandemic vaccination[42]. A study in the US, for example, found that those who previously had influenza vaccinations were more likely to consider the H1N1 pandemic as serious and were more positive about the safety of vaccines[57]. A survey in the UK of COVID-19 vaccine intentions likely found that past vaccination behaviour was a key predictor. The researchers, however, revealed potential confusion that may arise with individuals who were vaccinated for seasonal influenza believing that it would aid in COVID-19 immunity[5].

Higher risk priority groups. Due to higher exposure to viruses and disease, a large volume of literature also focusses on vaccine uptake by *occupations and in particular health care professionals*. Doctors and health professionals have been shown to have higher vaccination intentions and rates in general and also during the H1N1 pandemic, which is logical since they are often designated as priority groups[42]. The findings show that *pregnant women* who are also often a priority group are more likely to vaccinate, particularly when they have concerns about the disease[33]. Other studies showed that as with other groups, pregnant women were also more likely to be vaccinated if they believed it was effective[68]. Having a *chronic illness* or being the priority group for vaccination has also been associated with greater intentions to vaccine, once again logical given the awareness and priority allocation[28].

4. Ethics and Equity in the allocation of vaccinations

4.1 COVID-19 reveals structural inequalities

COVID-19 has had disproportionate effects across different social groups, exposing many of the structural inequalities in the UK and beyond. In the UK and similar nations, several core socio-demographic, regional and environmental factors have been attributed to an increased risk of certain groups to severe illness, hospitalisation and death from COVID-19[69]. The current pandemic has likewise exposed structural inequalities in which many of these traits intersect. As of October 2020, our understanding is that COVID-19 in the UK disproportionately effects the following groups:

- **People aged 65 and older**, where the highest number of deaths have been reported, with a considerably higher mortality rate in those 80 years and older[64].
- **Individuals living or working in crowded congregated settings**, particularly older adults living in senior care homes[70].
- Those with **underlying health conditions and co-morbidities** such as diabetes, severe asthma and obesity[69] are more likely to become hospitalised and die.
- **Ethnic minorities**, termed BAME (Black, Asian and Minority Ethnic) in the UK, have had an increased risk of death particularly for Black African & Caribbean, Pakistani, Bangladeshi and Indian ethnic groups, even after adjusting for multiple factors[69,71].
- **Men** in the UK and elsewhere are more likely to have poorer health outcomes die from COVID-19[69], with nearly two-thirds of the deaths in England and Wales between 9 March and 25 May being male[72].
- **Occupation** has also been shown to be an important risk factor with the highest deaths in England and Wales. In fact, examining deaths per 100,000 from March to the end of May 2020 in England and Wales, compared to male doctors, who had 30 deaths per 100,000, men in occupations with higher mortality levels were security guards (74), bus and coach drivers (44) and van drivers (37). The highest deaths for women were amongst care home and home care workers (26) followed by those in local offices carrying out national government administration (23) and sales and retail assistants (15.7), which were all higher than female nurses (15.3)[72].
- **Intersectionality** plays a key role in understanding these differences, a term which refers to how the combination of an individuals' characteristics result in structural inequalities. For instance, the occupations in England and Wales with the highest death rates also had statistically significantly higher proportions of workers from Black and Asian minority backgrounds[72].

4.2 Ethical principles for scarce vaccine resources

Four fundamental ethical principles have been suggested with regards to the allocation of scarce resources during a pandemic:

1. **maximise benefit** (save the greatest number of lives, improving people's length of life years by focussing on those with the best prognosis),

2. **treat people equally** (given that a first-come, first-served system, or one offering vaccination to those who can pay is not fair). If individuals have similar prognoses, vaccine access should be randomised. Randomisation for vaccinations in a 'vaccination lottery' has been previously been conducted in response to shortages[73]. Another suggestion could be location or cluster-based randomisation targeted at inhibiting transmission.

3. **promote and reward instrumental value** (reward those such as health care or front-line workers who both put themselves at risk but also save others); and,

4. **give priority to the vulnerable or worse off** (those who will become the most sick or die as a result of infection or to the young who will lose the most life years)[74].

Although rarely introduced, some have argued that we need to move beyond physical health to prioritise a fifth ethical principal, which are the longer term economic benefits of keeping certain jobs or parts of the economy functioning. Here the discussion is often linked to indirect effects such as excess mortality or the longer term effects of unemployment or bankruptcy on stress and mental health.

Following these ethical principles, those deploying the vaccine also need to transparently articulate the general priorities that guide their decision making. This includes core goals such as prioritising those most at risk of death or severe morbidity if they acquire the virus, those at risk of acquiring the virus, risks of negative societal and economic impacts if some individuals become ill (e.g., school teachers) or a focus on vaccinating those who are more likely to transmit the virus to others. These ethical values could also be interpreted differently in relation to whether they are based on benefits to health, social or economic purposes.

4.3 Interim advice of priority groups for COVID-19 vaccination in the UK

Defining priority groups using an age-based system. On September 25 2020, the Joint Committee on Vaccination and Immunisation (JCVI) of the Department of Health and Social Care provided interim advice on the groups that should be prioritised for COVID-19 vaccination when it is licensed in the UK[75]. The underlying principles that were proposed were to:

1. reduce mortality,

2. improve population health by reducing serious illness; and,

3. protect the NHS (National Health Service) and social care system.

Although articulated slightly differently, these ethical principles are generally in line with those listed above, namely, to maximise benefit (reduce mortality and serious illness) and instrumental value (rewarding and protecting NHS). There is, however, a less explicit focus on treating people equally and protecting vulnerable groups (beyond age, co-morbidity, health care workers, care homes) in addition to a stronger focus on protecting the health and social care system. The emphasis on protecting the NHS resonates in the UK since it is a national symbol, with slogans in early April 2020 stating 'Stay at home, protect the NHS, save lives', with weekly public displays thanking these key workers. As with many health care systems during COVID-19, the NHS remains at risk of being overloaded, particularly in certain geographical regions[76].

The JCVI review indicated that their advice was based on a review of epidemiological data on the impact of COVID-19 to date, Phase I and II data on vaccines and mathematical modelling of the impact of various vaccination programmes. They note considerable unknowns, noted above such as efficacy of the vaccine, safety across age and risk groups, effect on acquisition and transmission, transmission dynamics, duration of protection and the epidemiological, microbiological and clinical characteristics of COVID-19.

The committee takes a firm age-based approach, also with an emphasis on frontline health and social care workers and older adults living in residential care homes. The key priority and message is that it is an age-based programme for reasons of easier delivery and subsequently higher uptake. They note that this age-based approach in many ways overlaps with clinical risk factors. Frontline health and social care workers were also considered as high priority since they are at increased personal risk and will maintain resilience in the NHS and social care systems. Care home workers were likewise given a very high priority. Given that older adults living in residential care homes were

disproportionately affected by COVID-19 with a higher clinical risk of disease and mortality, this group also received one of the highest priorities for vaccination.

The committee noted that it was not possible to come to a firm position on priority groups, but produced an interim ranking combining an age-based approach with clinical risk stratification of 10 groups (i.e., older, high/moderate-risk, resident or worker in a care home and health workers), with the priority to be determined for the 11th group, which is the rest of the population. The committee notes "early signals have been identified of other potential risk factors, including deprivation and ethnicity" as well as for men. This interim approach that prioritises age, frontline health workers and those in care homes is an important first phase but does not consider broader equality ethical principles or prioritise the vulnerable in relation to known risk factors such as ethnicity, non-health high-risk occupations. Given that age is such a dominant factor in the absolute risk of severity and mortality, it may however, override these risk factors even if the relative risk is elevated for BAME or occupational groups.

Clarity and open engagement to manage expectations of the general public. There is also some confusion regarding the percentage of the general population that will be vaccinated to reach herd immunity. On October 4 2020, Kate Bingham, the head of the UK vaccine task force was quoted as saying that around 30 million people, less than half of the UK population could expect to be vaccinated. She was quoted as saying that vaccinating everyone was "not going to happen" and that "We just need to vaccinate everyone at risk"[77]. In this interview she noted that talking about vaccinating the whole population was misguided and clarified: "There's going to be no vaccination of people under 18. It's an adult-only vaccine, for people over 50, focusing on health workers and care home workers and the vulnerable." Other later media reports note that the NHS intend to be ready to vaccinate 75 to 100% of the population, sending highly mixed messages[78].

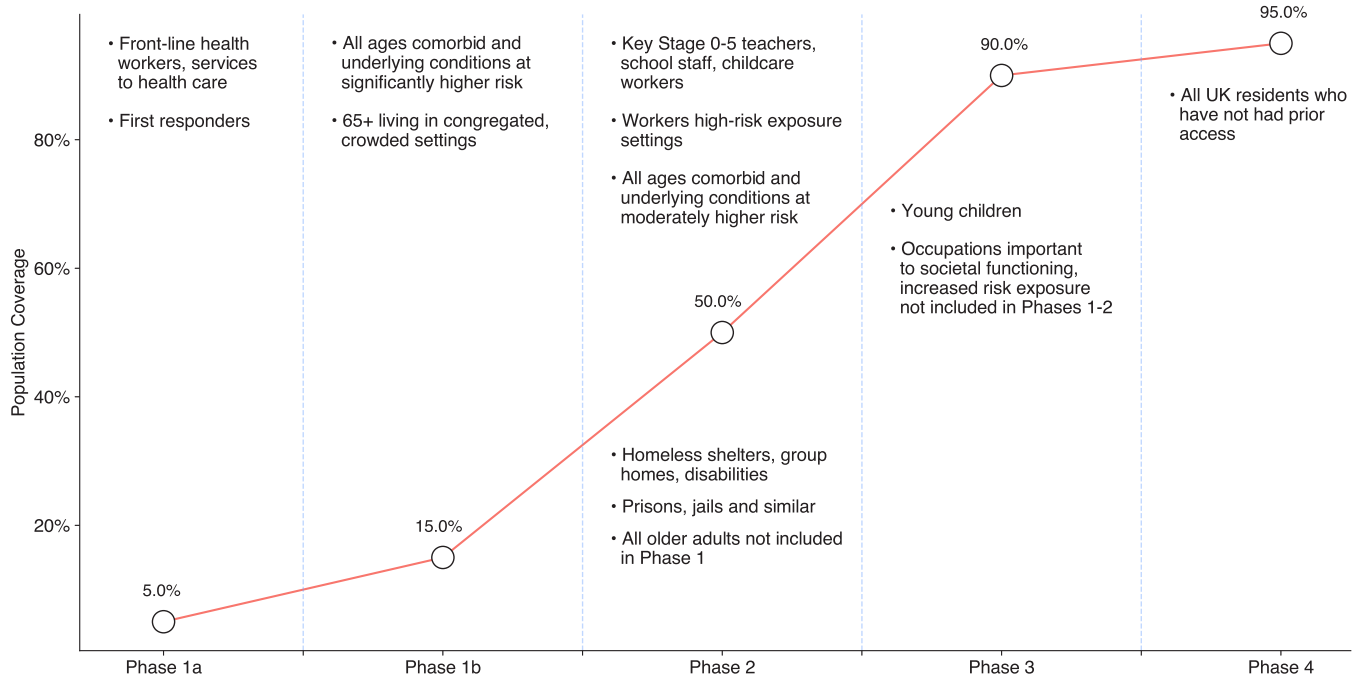
4.4 An alternative phased approach considering equity and the vulnerable

Given our knowledge about the unequal impact of the virus, another proposal for vaccine deployment could focus on rolling out the vaccine to more risk groups than listed above. Building on the US's recent National Academies report[11], previous experience of pandemic deployment[79], a similar phasing strategy could be adopted. For the purpose of illustration and fact that likely 80+% will need to be vaccinated, we adopt a higher level of coverage (95%) in our illustration compared to the UK's alleged less than 50% proposed coverage[77].

As Figure 3 illustrates, vaccine deployment could stratify groups into different phases to almost 95% coverage. Phase 1 includes those with the highest-priority to serve key societal needs such as health care workers, emergency services but also the most vulnerable populations with

FIGURE 3.

A phased approach to vaccine deployment and allocation for COVID-19



Source: Adapted from Figure S2 (National Academies 2020)[11]

significantly higher co-morbidity risks, or those in care homes. Phase 2 would include teachers, school staff and childcare workers but also those with less protection in high-risk front-facing occupations such as transportation, also given that these have some of the highest mortality rates in the UK[72]. During this early period, however, these groups likely did not use multiple non-pharmaceutical interventions such as mandatory face coverings and had lower protection.

A plan to protect the vulnerable might also include those with moderate co-morbidity risks, the vulnerable in homeless shelters, group homes, prisons, with disabilities and older adults already not covered in phase 2. The US model argued that Phase 3 could then focus on young children, additional occupations key to economic and societal functioning (see report[11] for detailed listing of all categories) with Phase 4 resulting the remaining UK residents. It remains a question, however, as to whether children would be a viable target group given that vaccine trials have not focused on this group.

Equity is an intersectional or cross-cutting aspect with certain groups also needs to be prioritised in different local and regional levels given large differences in social deprivation, age structure, ethnicity groups and population density[76]. Examining the concentration of individuals within the groups identified in each phase at the granular local level would be an effective tool for more targeted vaccine deployment.

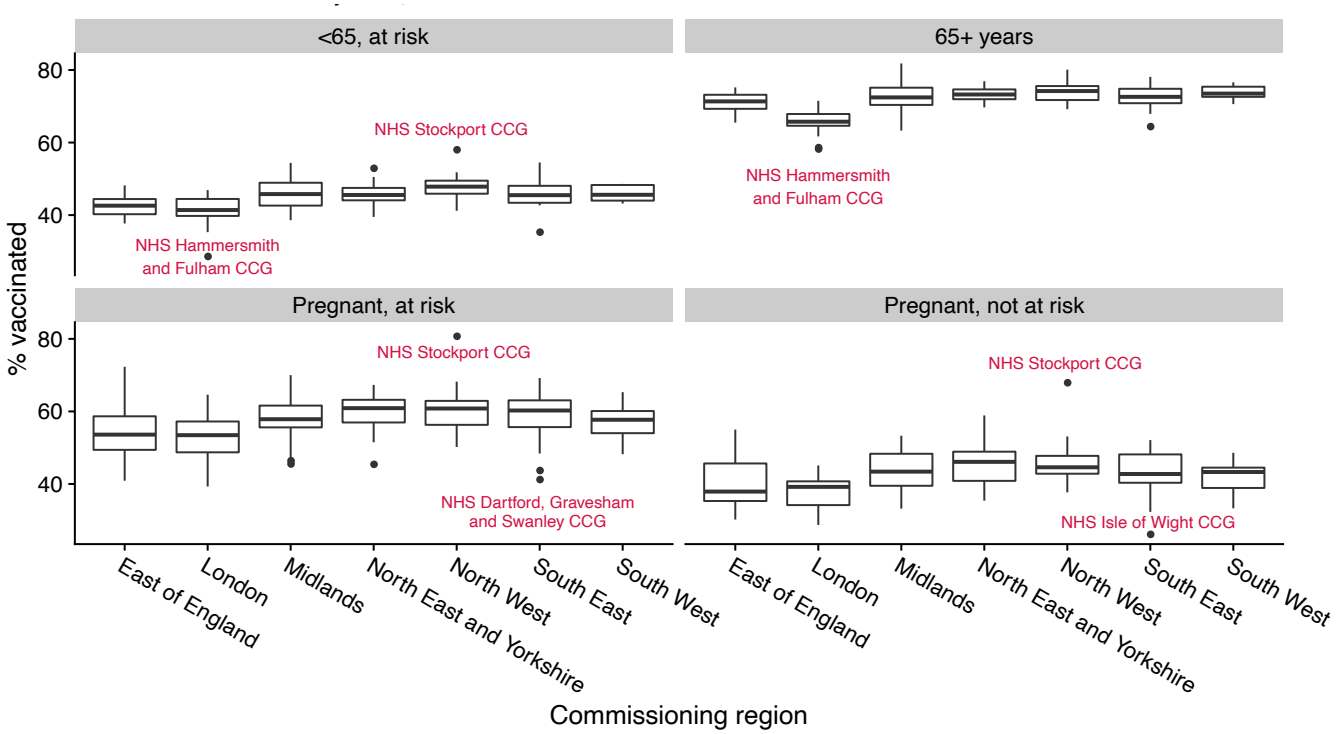
4.5 Challenges of practical deployment in a phased approach

4.5.1 Practical challenges

Although the previous phased proposal might at first glance seem ethically appealing and even feasible, similar approaches have failed. Given past experience of immunisation, certain factors are essential to take into account. First, it is necessary to define and locate those who have a priority status. Health care workers or those in care homes are more easily defined. Those with underlying conditions, however, need to be classified and contacted. GPs hold considerable data and could identify those most at risk to form an integral part of the vaccination deployment. Furthermore, although it is ethically desirable to give priority to those in prisons and the homeless, previous experience has shown that this is very mobile group and it may be difficult to achieve, track coverage and locate these individuals for a second immunisation. Although not defined

FIGURE 4.

Vaccine uptake in England, Seasonal flu vaccination by Clinical Commissioning Group (CCG), 2019 - 2020 by risk groups



Source: PHE (2020)[82]

in detail here, the definition of occupations essential to societal functioning need definition, which has been done elsewhere[11].

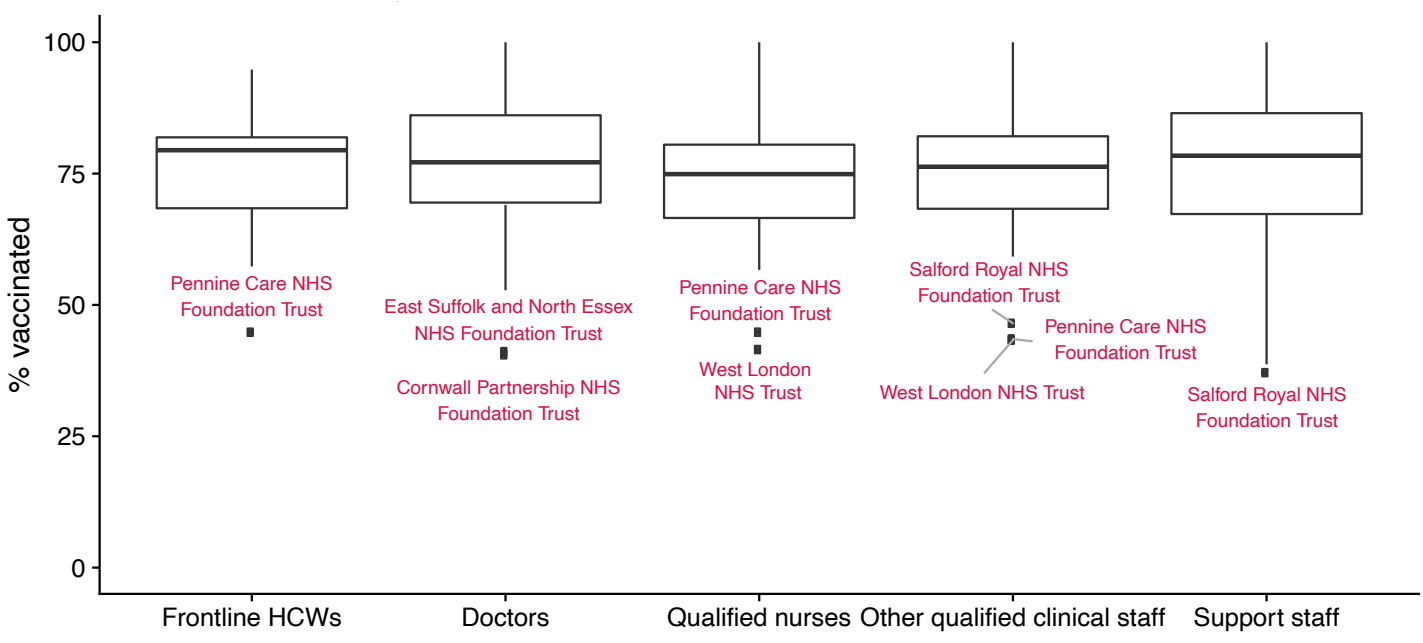
Second, priority groups based on age can be difficult to communicate. During the H1N1 influenza, age was chosen as a priority, with children prioritised over older people since the virus disproportionately affected the young. Since older populations were often targeted in the past for seasonal influenza vaccines, however, they felt alienated that they were not included in the priority group, resulting in considerable consternation[80]. Given that children are often a focus for many vaccines, similar confusion could also emerge if clear dialogue did not take place. When planning a vaccination campaign with priority groups, it is essential to develop a clear and transparent rationale to explain why these target groups have been chosen and the reasoning behind any ranking or phasing. Attention should be placed not only on priority groups, but also the 'excluded' to clarify the reasoning behind allocation with clear and targeted dialogue strategies. Although the prioritisation in Figure 3 is based on priority groups to limit harm, death and virus transmission, without proper discussion and public consolation a considerable backlash could arise. Without a clear rationale, there might be extensive negative debate for example, about why certain vulnerable populations in prisons or the homeless are prioritised before young children or certain seemingly vital occupations.

Third, although we present one stylised vaccination scheme, there will likely be multiple vaccines deployed at different times making communication highly complex and confusing. Media reports suggest that Britain has purchased 400 million doses across six different vaccines, spreading the risk[78]. This likely includes the Oxford/Astra Zeneca vaccine, which started a fast-track review on October 1 and the Pfizer vaccine on October 6. The intricacies of and differences between these vaccinations and the second generation ones that may follow will need to be expertly communicated to the population.

A fourth aspect concerns infrastructure and distribution. Although deployment plans are not publically available at the time of writing, media reports suggest that the plans will involve large NHS led 'Nightingale Vaccination Centres' and the army to distribute the vaccine[78]. It appears that existing systems for the influenza vaccination will be used in addition to a new hub-and-spoke model. Hubs will supply

FIGURE 5.

Vaccine uptake amongst health care workers (HCWs) England, Seasonal flu vaccination by NHS Trust, 2019 - 2020



Source: PHE (2020)[83]

the vaccine given cold storage (likely at -60°C) needs and related equipment with spokes taking the form of: mass Nightingale Vaccination Centres, mobile sites (potentially at polling stations) and roving teams. Reports suggest that roving teams could cover 9 households a day and fixed sites 2,500. To avoid the disruption of care, another option could be to carry out vaccinations during the weekend or evenings at GP practices. This approach, however, it not targeted at stopping or attempting to interrupt transmission in particular communities[81].

Finally, we must consider how to actually track and trace those who received the vaccination to ensure coverage, but also follow-up for a second immunisation. The vaccine developed by Oxford University, for instance, requires two inoculations that are 28 days apart. Given challenges with the track and trace system, considerable thought is required to achieve this goal, such as working with GPs and local communities.

4.5.2 Challenges of vaccine uptake across different groups

As shown in a previous section, the UK currently has one of the highest vaccination rates for seasonal flu in the world for those 65 years of age and older. But vaccination uptake differ across other age and risk groups, regions and type of health care worker. Figure 4 shows vaccine uptake in England for seasonal flu by Clinical Commissioning Group (CCG) in 2019 - 2020 by different risk groups[82]. The box plots show that there is some variation by CCG, with the names of some of the outliers listed in the graph. Here we see that there is broadly very high coverage of those 65 years and older, suggesting that COVID-19 will likely be very effective in this group. However, we also see a striking finding that those under the age of 65 and in the 'at risk' category show relatively low levels of uptake between 40-50%, suggesting that this group might be difficult to reach for COVID-19 vaccinations. Areas such as London also have lower overall uptake than others.

Figure 5 shows vaccine uptake amongst health care workers in England for seasonal flu vaccination in 2019-2020, demonstrating considerable variation across occupation, but also NHS Trust[83]. The figure illustrates wide variation of uptake across NHS trust. Although doctors, for instance, have high levels of seasonal flu vaccination it ranges from 40% in some of the smallest trusts to 100% coverage in others. There is also a wide range in vaccination levels for support staff, as low as 37% in smaller trusts up to 100% in larger trusts such as Blackpool.

5. History repeated: from misinformation to public dialogue

5.1 Anti-vaccination movements in the Nineteenth Century

Public understanding and support for vaccination are pivotal, yet an enduring challenge. Although some argue that the anti-vaccination or 'anti-vaxxer' movement emerged with measles, the MMR scandal surrounding Andrew Wakefield (discussed shortly) has multiple important parallels. In 1796, Edward Jenner presented an article to the Royal Society describing how cowpox could inoculate individuals against smallpox, coining the term 'vaccine' (from vacca, Latin for cow)[84]. The Vaccination Act of 1840 was introduced in the UK followed by the Vaccination Act of 1853, making vaccination compulsory for all infants and parents liable to a fine or imprisonment. This was extended in 1867 to the age of 14 and was one of the first acts that extended government powers in the name of public health[85]. Resistance to these laws grew with violent riots and demonstrations and the founding of the Anti-Vaccination League, which focussed on infringement of personality liberty and choice. What followed was the growth of a large number of anti-vaccination books and journals such as the Anti-Vaccinator[85]. After a large demonstration in 1885, a Royal Commission heard testimony (for seven years) and concluded in 1896 that vaccinations protected against smallpox but recommended to abolish penalties, thought to be a decision to appease the anti-vaccine movement. This resulted in the amendment of the vaccination law in 1898 to allow parental exemptions based on conscience, which was when the concept of 'conscientious objector' was introduced into English law[84].

Opposition also grew in other parts of the world such as in Sweden and particularly in Stockholm, opposition which emphasised an individuals' right to choose given uncertainty surrounding the effectiveness of vaccines, with vaccination rates subsequently falling to 40%. They quickly recovered, however, after a major smallpox epidemic in 1873 - 486. In the United States, smallpox became an epidemic in the 1870s, with states enforcing vaccination laws, and quickly passing new ones. Following the visit of leading British anti-vaccine campaigner William Tebb to New York in 1882, the Anti-Compulsory Vaccination Society of America was formed. This and related groups used pamphlets and legal battles and to eventually overturn compulsory vaccination laws in various states (e.g, California, Minnesota, Utah)[87].

The opposition to vaccines in the late 1800s has striking parallels with contemporary movements, namely in the ideas that: vaccines cause illness in children, immunity is temporary, vaccines are ineffective or poisonous, that medical science and government have created an alliance for profit, there is a cover up and move to totalitarianism and infringement of basic rights and civil liberties and that healthy lifestyles or alternative medicine is a solution[84,88].

5.2 The contemporary anti-vaccination movement

Although social media and the internet have altered the speed and manner in which anti-vaccination movements operate, there are multiple parallels in the 20th and 21st Century[89]. Similar arguments to those posited in the 19th Century are not unique and perpetuate across time. Some attribute current vaccine hesitancy to the 1955 'Cutter incident' where the US government vaccinated 200,000 children using a new polio vaccine. One batch from Cutter Laboratories accidently contained the live polio virus with 40,000 children contracting polio, with 10 dying and several hundred paralysed[48]. The anti-vaccination movement against pertussis (whooping cough) in the late 1960s for instance, in countries such as the UK, Sweden, Italy and former West Germany also had a detrimental impact on vaccination uptake and epidemics[90]. This was in stark contrast with countries that did not have vaccine resistance and had virtually 93 - 100% vaccine coverage and thus low disease in that period (Portugal, Hungary, United States)[90]. In the UK, a prominent health expert Dr Gordon Stewart claimed that the protective effect of the pertussis vaccine was marginal, coupled with a 1974 report about potential deleterious side effects of the vaccine which was in turn widely covered in the media. Loss in confidence of the public resulted in a sharp drop in coverage from 81% in England and Wales in the early 1960s to just 31% by the mid-1970s. This was followed by a pertussis epidemic[90]. The government reacted with a national reassessment of vaccine efficacy finding it had 'outstanding value in preventing serious disease'[91] in addition to financial incentives to doctors to achieve a target of vaccine coverage. The vaccine uptake soon rose to 93% with a dramatic decline in disease incidence, with just 1 death attributed to the disease in England in 2019[14].

Although there are numerous examples throughout history, the modern era of the anti-vaccination movement has been attributed to the now retracted 1998 *Lancet* study by British ex-physician Andrew Wakefield and 12 colleagues purporting a link between the MMR (measles-mumps-rubella) vaccine and autism. Although the study had a small sample size (n=12), an uncontrolled research design, and speculative statistical conclusions, it received widespread publicity and MMR vaccination rates sharply dropped. The retraction was a longer process, with a retraction from 10 of the 12 co-authors in 1998[92], accompanied by an admission from the *Lancet* that the authors failed to disclose financial interests (Wakefield was funded by lawyers of parents suing vaccine-producing companies). This was followed by only a complete retraction by the journal only over 12 years later in 2010[93]. A series of articles published in the *British Medical Journal* argued that the work was an 'elaborate fraud' which took place for financial gain[94,95]. This history has also been described in detail by journalist Brian Deer[96] with systematic failures in the system documented elsewhere[97].

Just as British anti-vaccination campaigner William Tebb travelled to the US in 1882, when removed from the UK, Wakefield found an alternate audience to perpetuate his beliefs. In addition to continuing his anti-vaccination activism, he recently directed the propaganda film 'VAXXED: From Cover-up to Catastrophe'. The film, which was later removed from services such as Amazon, alleges to show that there has been a cover-up by the United States' Centres for Disease Control (CDC) which in turn caused an increase in autism. The film has interviews with purported parents, journals and researchers who argue how governments and the pharmaceutical industry cover up evidence against vaccination[98].

5.3 Infodemic: Misinformation, anxieties and fear

On February 15 2020, WHO Director-General Tedros Adhanom Ghebreyesus announced at the Munich Security Conference: "We're not just fighting an epidemic; we're fighting an infodemic." Infodemics are characterised by an overabundance of information – both factual and misinformation – that occurs during a health emergency such as COVID. It was first coined in 2003 by David Rothkopf in relation to the SARS epidemic. It slightly differs from the WHO definition as "a few facts, mixed with fear, speculation and rumour," amplified by technology to create a disproportionate reaction[99]. Infodemics spread even faster than the virus, and are characterised by an excessive amount of information. This makes it difficult for both the public, but also public authorities, to identify an actionable path to counter misinformation and rumours. They not only hamper public health responses, but generate confusion and general distrust amongst the public[100].

Misinformation refers to misleading healthcare information, dangerous hoaxes with false conspiracy theories, and fraud that endangers public health. Given that the advice and information about the COVID-19 pandemic rapidly changes, it is an especially fertile ground which draws upon individuals' anxieties and fear by those seeking to promulgate anti-vaccination ideologies. Vaccine anxiety due to fear has been a constant when there is uncertainty and fear, which gives way to rumour[101]. The main contemporary

sources of the spread of misinformation occur on social media platforms such as Facebook, YouTube, Instagram, Pinterest, Twitter, Tencent, TikTok or previously through Google searches. It is notable, however, that the traditional mass media has also allegedly perpetuated this by covering misinformation[100]. Anti-vaxxers exploit shifts in recommendations and knowledge as the political and scientific establishment's failures. Narratives are aloof, unrepentant and aim at what they perceive as fallible medical and scientific experts.

5.4 Who creates COVID-19 misinformation and anti-vaccination material?

Conspiracy and anti-vaxx theories and misinformation entice individuals by linking aspects that might seem to be correlated. The WHO provides a 'mythbusters' site collating the main misinformation coronavirus messages (see Appendix 3 for a short summary)[102]. The demographics, socio-economic position and political ideology of those who spread and believe in anti-vaxx information is heterogeneous. The anti-vaxx group has often been characterised as being the polar opposite of the health conscious or what Berman (2020) termed "hippies with homeopathy" and conservative libertarians who see masks and vaccines as a sign of government oppression and an infringement of civil liberties[103].

An analysis of six of the most popular anti-vaccination Facebook pages (from 2013 - 2016) examined the social network, core topics and demographics of these groups[104]. This included the most popular sites, such as 'Dr Tenpenny on vaccines', 'RAGE against the vaccines' and 'Great mothers (and others) questioning vaccines'. They found that the majority (72%) who participated were women. This gender ratio is related to the focus of these groups largely on children's vaccinations, such as Dr Sherri Tenpenny's group or the 'Great mothers' who focus on vaccination as a 'mother's question'. This echoes the anti-vaccination movement in England from 1853-1907, where mothers were key in the resistance against childhood smallpox vaccinations[88]. This phenomenon is global with drops in vaccination in South Korea attributed to an active on-line anti-vaccination group called ANAKI (translated as 'raising children without medication')[105].

An analysis published in *Nature* of more than 1,300 Facebook pages with nearly 100 million followers produced a network map of pro- and anti-vaccination pages[106]. They found 124 pro-vaccine pages with 6.9 million followers and 317 anti-vaccine pages totalling 4.2 million followers. Whereas the pro-vaccine pages were global or national, the anti-vaccination pages were both locally and globally connected. Their study period of February to October 2019 coincided with a global measles outbreak, with anti-vaccine pages growing in this period by 500% compared to a 50% growth of pro-vaccine pages.

Anti-vaxx messages have particularly surged in the last 5 - 10 years helped by influencers on social media who largely focus on the false dangers of vaccines and offer alternative healing methods for infectious diseases that have effective vaccines (such as apple cider vinegar, or garlic), often for sale. Anti-vaccination Twitter messages linking vaccines with autism have been widely re-tweeted by the President of the United States Donald Trump[107]. There was a marked shift in President Trump's tweets, however, since early March 2020, with a positive focus on vaccines in relation to COVID-19[107]. In the UK, the influential rapper M.I.A. said she would 'choose death' over a coronavirus vaccine.

A variety of studies have shown that negative attitudes towards science are correlated with right-wing ideologies[108,109] and that political conservatives are more likely to believe in vaccine conspiracies[110]. A survey of adults in England (n=2,501) sampled by age, gender, income, and region found an appreciable endorsement of conspiracy beliefs. Around 25% showed some degree of endorsement, 15% a consistent pattern of endorsement, and 10% with very high levels[111]. Those with higher levels of endorsing COVID-19 conspiracy theories reported to be less likely to adhere to government guidelines, be tested, or vaccinated. They found that the groups who held general vaccination conspiracy beliefs also had a broader conspiracy mentality such as climate change conspiracy and a general distrust in institutions. A recent comparative report found that there was a recent surge in trust in some countries such as the US in the form of a 'rally around the flag' effect. A core finding, however, was the emergence of deep and polarised partisan divides[112].

The majority of anti-vaccination ads on Facebook are funded by two organisations, The World Mercury Group (led by Robert Kennedy Jr.) and the Stop Mandatory Vaccination group (run by Larry Cook who defines himself as a 'healthy lifestyle advocate')[113]. Others have linked anti-vaccination movements to Russian-backed Twitter accounts, with anti-vaccination messages found to target the US public[114]. In the Ukraine, for instance, vaccination rates went from 95% in 2008, to 31% in 2016. Some have partially attributed to targeted anti-vaccination bots from Russian-backed Twitter accounts[115]. A vital observation is that these targeted attacks do not only focus on anti-vaccination material, but also on pro-vaccination messages, suggesting that their main goal is to generate polarisation and divide.

5.5 The anatomy of anti-vaccine misinformation

To develop effective communication strategies to counter misinformation, it is important to understand the main strategies that are used. Our literature review found that the anti-vaccination and related conspiracy theory groups share several common elements (see Appendix 2, 3).

Distrust of science and selective use of expert authority. Distrust in science has grown substantially in recent years, with 55% of American adults in 2016 reporting that they trusted scientists 'a lot' about the risks of vaccines but only 39% on climate change[116]. A study of misinformation surrounding the Zika and yellow fever virus showed that attempts to refute misinformation about the virus failed because they had developed a general distrust and reduction of confidence in the WHO's epidemic information[117]. The distrust in science and supranational organisations such as the WHO reflects a general shift of individuals questioning the legitimacy of traditional institutions and favouring their own interpretations over evidence-based facts[104,118]. Ironically, the use of authority and selective experts to bolster opinion is a common approach of this group. The organiser of the recent anti-vaccination and anti-lockdown rally in London on September 19, 2020, for instance, was suspended Nurse Kate Shemirani, now coined the 'natural nurse' who argues that vaccines are poisonous and, related to 5G. She had a Facebook site with 14,000 followers, subsequently removed[119].

It also included Professor Dolores Cahill, of University College Dublin, and chair of the Irish Freedom Party who was reported to have told the rally "We want freedom, truth and love. I know that vaccines make people sick, you should not trust the Government, the doctors and the media, they are lying about the Covid-19 vaccine"[120]. These groups often leverage debates and updates on scientific knowledge, public health officials or those in government as a sign of doubt or significant disagreement, bolstering distrust in expertise. Another group of (previously respected but discredited) scientists move from topic to topic in order to 'merchandise doubt' with multiple examples chronicled by Oreskes and Conway, such as Frederik Seitz who moved from successfully creating doubt for decades about the detriment of cigarettes to a denial of climate change[121].

Distrust of pharmaceutical companies and government. A central driver of anti-vaccination beliefs is not only safety, but also a distrust in the commercial production of vaccines and the regulatory agencies overseeing them[32]. A persistent and strong driver of vaccine conspiracy beliefs centres around the claim that both large pharmaceutical companies and governments falsify vaccine data to further their own objectives and for profit[122]. This is often coupled with the claim that data on the effectiveness (or serious negative side-effects) of vaccines are hidden or covered-up by the pharma companies and the government bribing scientists and those in power (see Appendix 3). These narratives often refer to fallacies such as a hidden link between childhood vaccination for MMR and autism, regardless of the fact that this has been firmly disproved and revealed as fraudulent[123]. Since vaccines are manufactured by for-profit large pharmaceutical companies, often tied to scientists and governments, it is a relatively easy issue for sceptics to focus on. Since companies are driven by profit, there are real concerns from the general public that need to be addressed. Many recall the recent opioid epidemic in the US that caused many deaths, which eroded trust since it was related to drug companies compensating physicians. In 2015, a stunning 33,000 deaths in the US were attributed to opioid poisonings, a number rising to 43,000 in 2016 with an increased mortality rate of 268% from 1999 to 2016[124]. Experts in the field of vaccine anxiety and hesitancy such as Larson, Leach and Reich note that these concerns of the public mistrust need to be addressed. As Reich states: "some may dismiss these parental fears about vaccines as simply people who just don't understand how vaccines work, it behoves us to take their concerns seriously" (p. 8)[32].

Straightforward, simplistic explanations that are difficult to distinguish from truth. A hallmark technique is to reduce complexity, often tied to mistrust and rejection in science or alternative interpretations of scientific data[125,126]. A recent study of misinformation in relation to Zika and yellow fever concluded that it was difficult for individuals to decipher complex information in a rapidly moving and chaotic environment where little concrete factual information was available[117]. Another survey in the United States found that almost two-thirds of Americans reported finding misinformation in the form of 'fake news' confusing and around 25% reported that they themselves had shared fake news stories[127].

Use of emotion and individual anecdotes to impact rational decision-making. Larson argues that emotion is one of the main drivers in the evocation of fear and anxiety around vaccinations, and the perpetuation of rumours[89]. A hallmark of anti-vaccination information are individual and emotional anecdotes which are used as a primary source of evidence[128,129]. For childhood vaccinations, this often includes the story of one child that became ill, for instance, as told through the child's parents. These parental testimonies are often accompanied by visual pictures of children allegedly injured by vaccines, an approach that has been shown to strongly impact intentions to vaccinate[130].

The psychological literature has examined this use of emotions in impacting decision-making. When personal and anecdotal information is presented in a vivid and powerful way, it is said to affect people's general rational decision-making and reasoning[131,132]. This strand of research contends that vivid stories and anecdotes override rational thinking, a potential factor leading to lower vaccine uptake. Another mechanism is that these emotional experiences provoke anxiety, with individuals more likely to use faster intuitive thinking than more deliberate information processing. Experts in this area are quick to add, however, that those who are vaccine hesitant are not merely pawns to these tactics, but are rather driven by personal and legitimate fears and emotions that require conversation and dialogue[32,89].

An experiment found that exposure to rude or uncivil comments can polarise opinions and risk perceptions[133]. In an experiment of 2,338 individuals, all subjects read the same article on nanotechnology with one group reading a series of negative and uncivil comments and the other reading more polite comments. They found that the tone of the reader comments made a substantial impact on the way the readers interpreted what was in this case a particular technology. Anti-conspiracy arguments increased the intention to vaccinate only if it was presented prior to exposure to anti-vaccine conspiracy theories[134]. The effect however, was reduced if individuals believed in anti-vaccine theories or perceived vaccines as dangerous. Importantly, this study finds that once belief in anti-conspiracy theories are established, they are difficult to overturn.

Polarised communities: gatekeeping, information bubbles and echo chambers. Contemporary information exchange depends on the media, social networks and searchable web pages[135], which is where individuals seek information[125,136]. The Internet is one of the most important sources of health-related information seeking, yet finding information on vaccines or facts related to anti-vaccination claims is fragmented[118]. Few anti-vaxx sites are labelled as 'anti-vaccination' but rather focus on 'vaccine choice'[118]. These websites and Facebook groups are highly effective at engaging in social interaction to create a community of believers in contrast to pro-vaccine websites that often serve as a passive information repository with a complex deluge of information[137].

Vaccine deployment experts such as Larson argue that we need to move to examining the individual, with a focus on social networks[89]. Sites such as Facebook are seen as particularly powerful platforms to seek and share health information. This relies on community exchange and facilitation of peer social support and networking. Conversations on platforms and social media are often tightly controlled by gatekeepers[128]. Gatekeepers of Facebook pages, for instance, remove antagonist opinions and bar dissenting voices from participation. This communication within closed echo-chambers can exacerbate misunderstanding about scientific facts. The most common mode of participation on anti-vaccination Facebook pages is the sharing of material. A largescale Facebook analysis found that anti-vaccination networks were very large and active but had relatively sparse or 'loose' connections and did not interact for a sustained period of time[104].

An analysis of vaccine-related tweets in the Netherlands in 2017 isolated several densely connected networks that generally internally interacted with each other. These were, in order of size: the Dutch media (e.g., main news platforms, broadcasters), the health community (e.g., nurses, health services), writers and journalists, anti-establishment (e.g., patriotic, anti-Islam, pro-Trump), Belgian (Flemish) media, farmers and veterinarians, and global vaccine advocates. They found several prominent narratives and pathways of information. Scientific evidence and practical vaccination information was for instance often reported by the mainstream media and then shared by the vaccine advocates and health community. Conversely, the anti-establishment community shared information on natural medicine, theories related to Darwinian survival of the fittest (i.e., vaccines weaken the human race), and the freedom and infringement of rights and conspiracy. They often referred to online documentaries, such as the now banned documentary VAXXED, discussed above.

We know that online platforms tailor content feeds and adapt them to individual preferences. This means that individuals are increasingly in an information bubble that is aligned with their own interests and beliefs[138]. This means that those with anti-vaxx views are automatically exposed to more material and rarely receive other perspectives and those in favour of vaccines repeatedly 'preach to the converted' via a feedback loop. This results in what has been termed an 'echo chamber' where an individual's pre-existing beliefs are persistently reinforced by likeminded peers, which in turn reinforces polarised communities[139].

5.6 Dialogue and polarisation not misinformation: Knowledge voids and rumours

Social anthropologists who have studied vaccine anxieties and uptake across multiple global contexts for decades argue that the focus on misinformation is distracting. Or as Larson stated "A focus on misinformation is like cutting the head off of a weed, missing the real underlying problems" (personal communication). Leach and Fairhead (2007)[101] and Larson (2020)[89] contend that public acceptance of vaccination is not the result of misinformation, but rather an information and knowledge deficit or void. These researchers focus on how risk, trust and rumour underpin vaccine anxieties and resistance. Importantly, this approach does not view parents or individuals as easily influenced by the ubiquitous anti-vaccination movement. Rather, they argue that individuals make decisions based on their personal and local experiences and that their concerns are valid and need to be understood via dialogue. Leach and Fairhead explain that parents make a decision about the vaccination of their child not in relation to risk at a population level (as it is often presented in terms of X number of risks per 1,000 or other metrics), but rather of the health history of the child, family and their personal experiences with institutions[101]. It is for this reason that personal anecdotes and individual stories resonate.

Vaccination can also take a political dimension when international campaigns are disconnected from local and national services, inviting suspicion[101]. The distrust and boycott of polio vaccines in northern Nigeria in 2003 emerged from a longer contextual history related to the erosion of public trust and subsequent spread of rumours that lead to the rejection of vaccinations[140]. A recent election polarised the country, allowing rumours to quickly spread that the vaccine was engineered by the West and contained HIV, cancerous and sterilisation agents, particularly aimed at Muslims. By January 2004 there was an alarming 30% increase in polio. The central policy recommendations from this Nigerian experience were to understand first why people have concerns and fears about the vaccination and then to actively debate and discuss these concerns. Communication is therefore not passive, uni-directional, or providing detailed information on a webpage, but rather a dialogue that is participatory, iterative and sensitive to local politics. They were also able to raise public awareness through something that was engaging by using well-known and local musicians and in a language and type of communication that resonated. They also demonstrated how the exclusion of certain groups, such as prominent Muslim leaders, in the federal response to the boycott created additional resistance. Particularly the sustained involvement of local and community experts and leaders is essential.

6. Conclusion and policy recommendations

A recent DELVE report[10] outlined the core factors related to vaccine development in addition to the production, supply chain, distribution and administrative issues, and they are therefore not discussed in detail here. We focus on what we can learn from a social-behavioural response to vaccine deployment, with attention to learning from history, other vaccine deployment efforts and attention to misinformation and dialogue, in order to formulate policy recommendations.

6.1 Dialogue and community engagement

Perhaps one of the most important lessons that can be drawn from this literature is that a serious and well-funded COVID-19 community-based dialogue and engagement strategy is essential for effective vaccine uptake.

Open, transparent and immediate dialogue must begin over vaccine deployment with the general public. The promise of a vaccine in early or mid-2021 has brought high public expectations. Confusion, anger or distrust may emerge if expectations are not managed in relation to phasing of vaccination delivery and the timing of the vaccination rollout. The phasing of vaccination delivery as proposed in this report and elsewhere will only work if it is perceived as fair by the population. If the rationale is clear, there is sufficient public debate, and if there is transparency in decision-making and distribution, acceptance will be higher[80].

Debate also includes clarifying that we are operating under conditions of uncertainty and what that means, while developing an understanding of the percentage of the population likely to be (and indeed required to be) vaccinated is essential. Openly addressing uncertainties about efficacy and safety, explaining which groups will have priority for which reasons must be a priority. Without transparently outlining the ethical principles and managing expectations, vaccine deployment could be ineffective, generate distrust, and lack of adherence. Given that up to 75% vaccine coverage would be required for a vaccine with an efficacy of 80%, it is essential to manage public expectations in order to clarify the fact that if vaccine efficacy is lower or if coverage is hindered, a longer-term hybrid situation will be required (e.g., test-trace and isolate combined with face coverings, social distancing) while we live with the virus for longer period of time.

Enhance public debate, promote the ethical understanding of prioritised risk groups, and provide clarity on the more realistic and longer time-scale of vaccination roll-out. The promise of a vaccine in 2021 has brought high public expectations. Confusion, anger or distrust may emerge if expectations are not managed in relation to phasing of

vaccination delivery and the timing of the vaccination rollout. The phasing of vaccination delivery as proposed in this report and elsewhere will only work if it is perceived as fair by the population. If the rationale is clear, if there is sufficient public debate, and if there is transparency in the decision-making and distribution, acceptance will be higher.[80] As discussed previously, basic ethical principles must also be upheld. The public has to agree that vaccine deployment is ethical and fair, which requires their engagement. They must also experience the transparency of any decision-making processes in order to see how vaccine deployment is being developed, but also how it is adapted in response to challenges or problems. Trust and confidence are enhanced by clarity in the form of communication of the best and most up to date scientific information is deployed.

Dialogue and community engagement predicated on scientific evidence, where the following elements are vital:

- Balanced messaging about risks that match everyday experience
- Time is required for transparent public debate to develop an ethical understanding of prioritised risk groups and vaccine deployment
- An enhanced public understanding of the uncertainty of COVID-19 vaccinations, ethical principles, expected barriers, safety and efficacy, including expectation management with regards to any potential changes in the response due to new scientific knowledge, threats and public input, potential adverse effects, regularly reviewed by expert and independent scientists
- Active monitoring of the public's concerns, beliefs and debates through multiple channels
- Active work on dialogue with the public, more than uni-directional communication and information, which is necessary to fill information gaps and counter misinformation transmitted via multiple channels
- Management of expectations about the timing and roll out of the vaccine, anticipating potential supply and distribution problems by 'under-promising and over-delivering' to maintain public support
- Engagement in coordinated policies and communications through all nations and local communities within the UK to avoid public confusion and avoidance of doubt
- Engagement not only in centralised government communications, but also the provision of 'tool kits' to support and actively work with local authorities and communities by engaging with local stakeholders to reach diverse populations
- Work with diverse stakeholders to reach communities and individuals with a history of vaccine hesitancy or exposure to misinformation
- Messaging which is multi-language, visual and appealing
- Take engagement to the places where people frequent (e.g., social media, religious groups) that counters well-known perceived and actual barriers to vaccination instead of expecting that they will only seek out official sources
- Messaging around the timing of the supply and distribution are key, with the advice to 'under-promise and over-deliver' being pivotal in the generation of public and political support[79]
- Build on successful vaccination strategies (e.g., influenza, childhood vaccination), of international organisations such as UNICEF or the Red Cross and Red Crescent Societies who have experience of communicating risk in emergency situations

We now elaborate on several of these points discussed in the short summary below.

Balanced messaging on personal and societal levels of threat that match everyday experience. Individuals need clear information on their personal and societal levels of threat that is clear and balanced. A variety of countries have had mixed experiences with introducing mandatory vaccinations, banning school children who have not been vaccinated or backlashes from public health vaccination campaigns from previous pandemics. A survey in France conducted around the peak of the H1N1 pandemic found that the public rejected the mass vaccination campaign from public health authorities[28]. The central reasons reported which were reported were perceived to regard over alarming health messaging which aimed to increase an individual's perception of the severity of risk. This danger and threat was not present in the individual's daily and personal experiences and thus the threat was not confirmed. In addition to this, another central critique was that primary and local physicians were not involved in the campaign, which was pivotal in other related studies.

Clarity on safety, efficacy and vaccination schedule. Individuals need to know and understand that the vaccination is effective, particularly across risk groups, which remains unknown for some groups at the time of writing. Practical aspects such as the length of protection, vaccination schedule, or the need for boosters must also be clear. Clarification on the safety of this vaccine is paramount given concerns and public debate surrounding rapid development and the underrepresentation of certain groups in the trials[47].

Move from global and national messaging to mobilising local communities. Previous pandemics such as H1N1 and Ebola have taught us that it is essential to leverage and use existing structures and relationships such as local authorities, general practitioners, pharmacies and local groups[89]. A recent analysis of pro- and anti-vaccination Facebook pages showed that the pro- and anti-vaccination groups operated on different 'battlefields'[106]. Whereas pro-vaccine groups and pages were largely globally and nationally connected, the anti-vaccination pages were both globally but also locally connected. Different groups also focus on different goals. The main goal of pro-vaccine groups is to ensure that people get vaccinated, which is not engaging and rarely sufficiently interesting to a general audience. In contrast, anti-vaccine groups often focus on multiple seemingly urgent health and safety topics which makes them more appealing to a large group of people who are undecided and are seeking information. They also engage directly with individual's experiences, anxieties and daily life with anecdotal evidence[101]. In turn, this allows anti-vaccine groups to be more agile and responsive to diverse concerns.

Engage in conversation and dialogue, not reactive challenges, respecting emotions. Messages that are directly 'reactive' to a challenging a piece of propaganda are often futile. This has the potential to create a backlash, where a series of heavy informational and detailed exchanges are ineffective[103,141]. Others have argued that it is important to take the concerns of individuals with vaccine hesitancy seriously and dispel misinformation[103]. In the case of childhood vaccinations the resistance stems from parents wishing to protect their children; legitimate concerns that need to heard and understood[32].

There are several key strategies used by the anti-vaccination movement that are in stark contrast from neutral, rational and often complex scientific messaging. A stronger approach is likely to adopt the methods used by the anti-vaccination and conspiracy movement. This is centring stories on anecdotes which are personal and often highly-emotional narratives. This could be in the form of an 'uneventful' vaccination where nothing happened to provide security. A powerful and often used narrative is the 'conversion' of an anti-vaxx to pro-vaccination ideology. Examples of cases include previously anti-vaxx parents whose child was saved from a tetanus shot after almost dying[128]. Common suggestions are to use prominent influencers or local COVID-19 Vaccine Ambassadors who can provide counselling. Finally, peer-to-peer contact and interaction has been shown to be very powerful.

Counteract misinformation and knowledge voids. As noted elsewhere, it is no longer enough for scientists and governments to merely clarify communication[116]. Active online strategies to counteract campaigns of mis- and disinformation are required. Science has been promoted in many countries as the most rational weapon against misleading information and irrational evidence. China, for instance focussed on ending COVID misinformation through scientific information with the media slogan "rumours end with the wise".

Government transparency and freedom of expression. Although it is important to counter and remove harmful misinformation, it is vital that this does not undermine transparency, freedom of expression and debate such as challenges to the accountability of government, health authorities and scientists. This role remains important for the public but also contributes to vigorous debate and the necessary fact-checking by journalists and scientists to the provision of balanced information to the public. When those arguing on the basis of misinformation are brought in to media debates as supposed 'balanced representation' alongside mainstream scientists for sensation, this can undermine accurate information and result in confusion. This happened more recently in debates around herd immunity where a fringe group of scientists lacking evidence, a publication track record or concrete policy advice, were given a substantial voice.

Tailored dialogue. The review found that five central behavioural factors are related to vaccine uptake: (1) complacency (perception of risk, severity of disease), (2) trust and confidence (efficacy, safety), (3) convenience (barriers, access), (4) sources of information; and, (5) socio-demographic characteristics (e.g., education, sex, ethnicity, religion, past vaccination behaviour).

Convenience: reducing barriers and leveraging existing stakeholders. It is vital to ensure that practical aspects are considered. This includes considerations of the multiple locations for vaccinations such as within local physicians' offices, schools, or pharmacies to counter inequalities in access. This includes transportation and the ability to reach vaccination sites, or compensation or concessions for time off of work. Documentation barriers need to be lowered, with problems when a card is required. Covered elsewhere in the DELVE report[10] and recent National Academies report[11] in the United States, is the issue of ensuring that the supply distribution is both timely and appropriate. Experiences from H1N1 and other mass vaccination deployment shows that effective distribution systems are key for tracking distribution and that the supply is timely and the right amount. This includes clear communication with those who produce the vaccine, provide the inventory and monitoring and distribute it locally. Building upon existing infrastructures that function well such as childhood or emergency vaccination programmes or international efforts is key.

6.2 Inoculating the public against misinformation, accountability and enforcement

Beyond dialogue and building understanding this rapid review of the literature can also offer policy suggestions related to misinformation.

Empowering the general public: spotting and reporting misinformation. An important practice is to promote media literacy and empower citizens to spot and report misinformation. Governments such as Singapore and China not only engaged in legal and authoritative measures to stop misinformation, but called for social support from the community to stop rumours and battle misinformation. In particular, vulnerable groups such as children or those with lower levels of media literacy are vital to reach. National governments and supra-national organisations have attempted to counter infodemics by developing findable platforms with correct information. The WHO Information Network for Epidemics (EPI-WIN) was set up early in the COVID pandemic with the aim of using a series of amplifiers to share tailored information with specific target groups[100]. The WHO also launched a chatbot on Facebook Messenger[142] and a health alert on WhatsApp[143].

Reliable COVID-19 sources include:

- The COVID-19 Poynter Resources from the International Fact-Checking Network (IFCN) coordinated by the United Nations: https://www.poynter.org/coronavirusfactsalliance/
- WHO Mythbusters site: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public/myth-busters
- Google COVID-19 warnings which includes general information (if location services are not disabled, the latest locally-optimised health information): https://www.google.com/covid19/
- The province of Québec for instance prepared a site for the public to use online fact-checking services called the Détecteur de Rumeurs (Rumour Detector), http://www.scientifique-en-chef.gouv.qc.ca/en/dossiers/chercheurs-et-sphere-publique/detecteur-de-rumeurs/)
- The WHO offers a site that contains the links of how to report misinformation for the largest media sites; https://www.who.int/campaigns/connecting-the-world-to-combat-coronavirus/how-to-report-misinformation-online

Accountability by media companies for risks to public health. Given that the majority of anti-vaccine misinformation is largely tolerated on social media and large platforms such as Facebook, Instagram and Twitter, a clear recommendation is that these companies take responsibility by enforcing their own policies to avoid distributing COVID and health misinformation and hoaxes that endanger public health. One the early approaches from organisations such as the WHO was efforts to ensure that individuals were directed to a reliable source such as the WHO, public health or centre for disease control in their relevant country[100]. In mid-March 2020, Google said it was committed to removing misleading information about COVID-19 from YouTube, Google Maps and its development platforms and in advertisements[144].

One of the strongest deterrents, however, seems to be a boycott of social media companies by a powerful alliance of major advertisers, such as Unilever and Mars, who boycotted all advertisements until Facebook and YouTube agreed to remove harmful content[145]. The companies had long protested their advertisements placed alongside conspiracy, anti-vaxx and other harmful content. In early April 2020, Twitter noted that it would check whether accounts were credible sources of information and monitor conversations to ensure that keyword searches for COVID-19 would lead to reliable information[146].

Many conspiracy theories have been widely spread by the well-known QAnon, which has produced many viral conspiracy theories including Pizzagate[147] and those focussing on accusing liberal Hollywood actors and US Democratic politicians. Thousands of QAnon-affiliated accounts were banned by Twitter in July 2020, who then allegedly changed the algorithm to reduce the spread of their messages[148]. Facebook also moved to restrict and remove QAnon activity as part of its crackdown on extremist conspiracy theories in the summer of 2020, which included millions of users spanning 790 groups and 300 hashtags across Facebook and Instagram[149]. Others such as YouTube and Amazon eventually removed conspiracy films such as Plandemic, but only after they were watched by millions[98]. Facebook is now also actively countering misinformation about itself as an organisation in response to the Netflix documentary 'A Social Dilemma', where it clarifies that they are taking steps to reduce content that drives polarisation and fight fake news, misinformation and harmful content. They note that in the second quarter of 2020, they removed over 94% of hate speech before it was reported[150].

Bring in legislation and enforce criminal prosecutions for spreading misinformation. Several countries have clearly defined information that is harmful and a threat to public health. A study of the three Asian countries (China, Singapore and South Korea), evaluating 5,000 news articles and policy responses revealed several main strategies to counter COVID-19 misinformation[151]. A prominent strategy was clear legislation and punishment of those who produced and disseminated false information. The actual prosecutions were then shared regularly and prominently with the public in addition to persistent reminders of laws that could be used to prosecute those guilty of spreading misinformation. Singapore, for instance has the Protection from Online Falsehoods and Manipulation Act (POFMA), with four prominent cases within the first months of the COVID-19 outbreak. POFMA also lifted any exemptions for internet intermediaries which legally required social media companies like Google, Facebook, Twitter and Baidu to immediately correct cases of misinformation on their platforms[151].

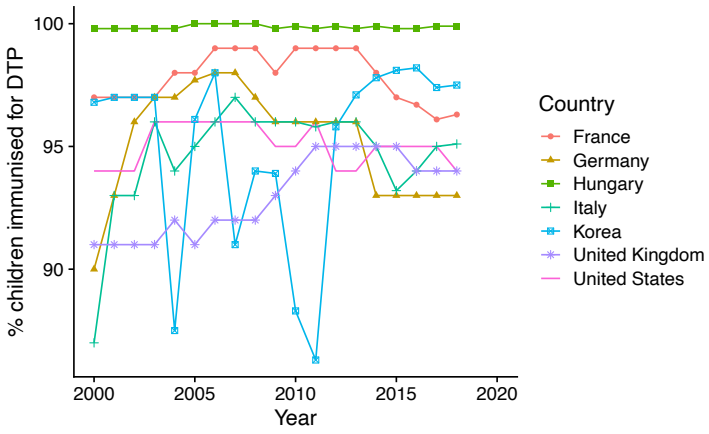
Monitoring nefarious misinformation spread by local and foreign actors. As many national governments, the European Commission has adopted the monitoring of false or misleading narratives by foreign actors. In their published strategy to tacking coronavirus disinformation, they contend that 'foreign actors and certain third countries, in particular Russia and China, have engaged in targeted influence operations and disinformation campaigns in the EU, its neighbourhood, and globally'[152]. As discussed previously, others have linked anti-vaxx information to organised bots and activities targeted at particular populations, which remains an area of concern[115].

Learning from history, international examples and past pandemics. This review of the broad scientific literature found several commonalties across history, past pandemics and potentials to learn from other nations. Anti-vaccination movements in the 19th Century share many communalities with contemporary debates; anti-vaccination messages from experts, religious leaders, and key media sources since the 1960s (e.g., against pertussis, measles) have been associated with a drop in uptake and subsequent spread of viruses. Uptake for the H1N1 2009 - 2010 vaccine was markedly lower than anticipated, attributed to problems in the timing of supply and communications. Uptake was higher when previously successful programmes were used, such as school vaccination clinics. Countries such as Singapore and South Korea have actively worked to debunk rumours through coordinated action[151]. This included disseminating FAQs with experts, government officials and health authorities. In Singapore, five ministries joined to create correction of information and advisories via diverse platforms such as targeted digital advertisements at the local level in neighbourhoods, and Facebook, Instagram pages belonging to government ministries and officials and push channels in WhatsApp.

Appendix 1. Childhood DTP and Hepatitis B vaccination uptake, selected countries 2000-2019

FIGURE A1.1

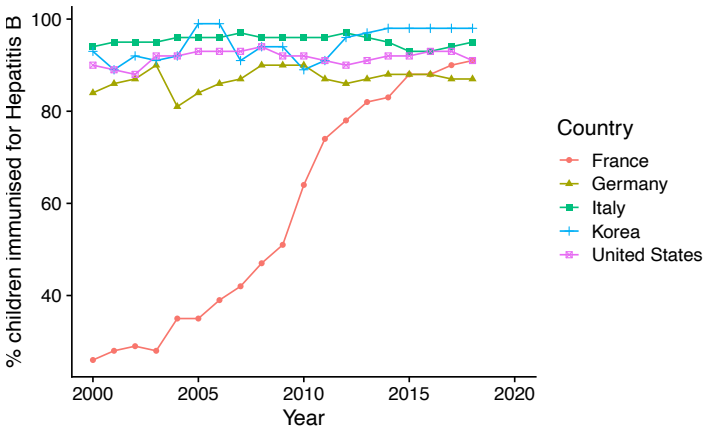
Percentage of children immunised for Diptheria, Tetnus and Pertussis, Selected countries, 2000 - 2019



Source: OECD (2020)[9]

FIGURE A1.2

Percentage of children immunised for Hepatitis B, Selected countries, 2000 - 2019



Source: OECD (2020)[9]

Appendix 2. Data and methods

For the sections examining behavioural and socio-demographic factors related to vaccine uptake and hesitancy, there were sufficient systematic reviews and information that could be collected and reviewed. This was achieved using the main search terms in Table A2 and limiting them to human studies. Given the lack of systematic reviews on misinformation and conspiracies around vaccination, a more systematic review approach was adopted for that section. Using a custom-built library which called various APIs, we included all studies that were returned from the three leading bibliographic databases (Scopus, PubMed and Web of Science). Due the rapid shifts surrounding the currently COVID-19 pandemic, we also included some pre-print and other material from prominent databases (MedRxiv, PsyRxiv, bioRxiv, SocRiv) in addition to some media reports and books on the topics. There was no selection on language but the majority of the articles are in English. We included all research designs and human studies only.

The literature reviewed here largely includes: systematic reviews, several quantitative attitudinal surveys, qualitative studies, historical accounts and analyses of social media. There is a large amount of literature in this area of research that does not contain new research but rather editorials and comments. These have been excluded from the current review. We first searched for these main search terms, paired with one of each of the terms listed below in Table A2.

TABLE A2

Search terms used in systematic review

Main search terms	Paired by one by one with each of
'vaccine', 'vaccination', 'vaccinate', 'immunise', 'immunisation', 'immunize', 'immunization', 'inoculate', 'inoculation', 'anti-vaccination', 'anti-vaccine', 'anti-vax', 'vaccine hesitancy', 'barriers', 'vaccine procurement', 'knowledge', 'attitude', 'perception', 'expectation', 'opinion', 'behav*', 'misinformation', 'conspiracy'	'attitude', 'perception', 'expectation', 'opinion', 'behav*', 'misinformation', 'conspiracy'

A flow diagram of the articles examined in this review including the screening, eligibility process will be provided with the final peer-reviewed academic publication of this relevant portion of the report.

Appendix 3. Main vaccine and COVID-19 misinformation and conspiracy theories

There have been a variety of vaccine and COVID-19 related conspiracy theories with the central ones summarised here, with a 'mythbusters' site collated by the WHO[102].

No vaccine is needed since COVID-19 is a hoax. This theory poses that COVID-19 does not exist and is popular with professional conspiracy theorists such as David Icke (notable for arguing that the world is controlled by reptilian elites) and InfoWars owner and host Alex Jones. A popular film on YouTube that has been viewed millions of times is by Dr Annie Bukacek, a member of the Montana Health Board who argues that COVID-19 death certificates are being manipulated[153].

Bill Gates and the vaccination plots. Multiple conspiracy theories have involved sub-plots around Bill Gates. A prominent video entitled 'Plandemic' on YouTube was watched by millions of viewers before being removed by YouTube and Facebook under their definition of dangerous misinformation. It focused on a 2015 Ted talk given by Gates where he discussed the Ebola outbreak and warns of a new pandemic which was used to claim that he knew the pandemic was coming or purposely caused it. This is linked to a supposed plot of Gates to vaccinate the world's population. The other popular sub-narrative is that Gates uses vaccination programmes to implant digital microchips to track and control people. This has been widely spread by QAnon, a group discussed elsewhere within this report.

COVID-19 vaccinations are a plot by big pharma and scientists to make money and, that natural medicine is more effective. Here the focus is that evidence-based conventional medicine does not work and is a plot by pharmaceutical companies and scientists to make people ill for profit. Some of the large anti-vaxx and hoax influencers also appear to monetise their message in some cases. Some sell miracle multi-purpose pills to cure or prevent COVID (Alex Jones, Dr Marcola, NaturalNews). InfoWars founder Alex Jones, for instance, was purported to become very wealthy from spreading a variety of conspiracy theories[154] and selling bogus coronavirus cures[155]. These individuals monetise false preventative natural, traditional or homeopathic treatments such as consuming large quantities of their own medicine sold on their site, or a particular diet (garlic, lemons, ginger, vitamin C, alkaline foods, a keto diet)[156].

Another common sub-narrative is that key scientists involved in advising governments stand to personally profit from a COVID vaccine. One example is the alleged claim that Dr Anthony Fauci owned a protein patent that forms part of SARS-CoV-2[157]. In September 2020 a claim alleged that Sir Patrick Vallance, England's Chief Scientific Advisor who previously worked at pharmaceutical company GSK (the company contracted to develop a COVID-19 vaccine), would profit from the COVID-19 due to shareholdings[158]. The government reported that this is not a conflict of interest since he was not involved in the commercial decisions regarding coronavirus vaccines.

This is in addition to a variety of other conspiracy theories such as that the **virus is caused by 5G mobile phone towers**. This theory is not new and was previously alleged with other viruses and 2G-4G towers. Although it is biologically impossible for viruses to spread by waves or photons across the electromagnetic spectrum, this theory did gain some traction. Within the UK the pandemic hit just as the government voiced security concerns and discussion about the rolling out of 5G built by Chinese companies and became mixed with conspiracy theories about the virus. Several celebrities with very large followings (Woody Harrelson, Anne-Marie) began sharing 5G conspiracy narratives. Other theories included that the virus could not survive in hot weather, that taking hydrochloroquine has clinical benefits, or that the virus is part of a Chinese bio-weapons programme.

Appendix 4. Preparation of Report

Report prepared for the SET-C Group by

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DISCLAIMER

This paper has drawn on the most recent evidence as of 21 October 2020 and has been subject to formal peer-review. Further evidence on this topic is constantly published and the Royal Society and British Academy may return to this topic in the future. This independent overview of the science has been provided in good faith by experts and the Royal Society and British Academy and paper authors who accept no legal liability for decisions made based on this evidence.

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