ECDC TECHNICAL

Countering online vaccine misinformation in the EU/EEA

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Executive summary

Vaccines authorised by the European Medicines Agency for use in the European Union (EU) are known to be safe and effective in preventing infectious diseases. Nonetheless, misinformation that incorrectly links these vaccines to harms to health or other undesirable consequences has, over recent years, continued to proliferate online and elsewhere. Misinformation about vaccines is not a new phenomenon, but it has become more prominent due to the rise of social media and, more recently, due to the emergence of the COVID-19 pandemic. The pandemic has clearly illustrated how easily misinformation can spread online and how rapidly new narratives can emerge and evolve. Vaccine misinformation can be dangerous: it decreases confidence in vaccines and can lead to vaccine hesitancy and reduced vaccination uptake.

Public health authorities can play an important role in identifying and countering online vaccine misinformation to limit the harm it can do to a country's vaccination efforts. In order to do this effectively, however, they need to have a good understanding of the landscape of vaccine misinformation in their respective countries, and of the tools and strategies that are available to fight misinformation effectively. This study, commissioned by ECDC, thus set out to explore:

- The main sources of online vaccine misinformation in the EU/European Economic Area (EEA);
- The evidence base for how to counter online vaccine misinformation;
- The current strategies used by national public health authorities in the EU/EEA and other organisations to counter online vaccine misinformation; and
- The training needs of national public health authorities in the EU/EEA for how to develop effective strategies for countering online vaccine misinformation.

The study applied a mixed-methods approach consisting of qualitative and quantitative research methodologies, including a literature review, interviews with representatives of national public health authorities of six EU Member States (MS) and several pan-European and global organisations involved in countering vaccine misinformation, and a social media analysis in the six selected countries (Estonia, France, Germany, the Netherlands, Spain, and Romania). The focus of this study was misinformation relating to vaccination against measles (in combination with mumps and rubella), human papillomavirus (HPV), influenza, and COVID-19.

The findings from this study provide insights for national public health authorities into the factors behind the spread of vaccine misinformation online and the options and capacities needed for responding to it. The findings will also serve to inform the development of a training package to support those authorities (and other interested organisations) in their work in this area.

Study findings

Vaccine misinformation is rooted in part in a lack of basic understanding of how vaccines work and how they are developed. As has been well exemplified over the course of the COVID-19 pandemic, this applies especially in the case of newly developed vaccines, when health authorities and decision-makers must rely on evolving information. Challenges with communicating such information may contribute to conditions that are conducive to the spread of misinformation.

At the same time, simply publishing scientific evidence is not sufficient to affect people's beliefs when there is so much contradictory information available. Debunking – the process of correcting erroneous claims by providing counter-arguments to messages containing misinformation – can be an effective means of addressing specific myths or misconceptions, but it is reactive and does not necessarily protect people from future misinformation threats. Longer-term resilience to vaccine misinformation depends to a large extent on a person's level of digital, health, and science literacy. The spread of misinformation halts when a person can correctly identify misinformation by applying critical thinking skills to assess the credibility of a source and the content of the message. However, distinguishing between trustworthy and false information is not always straightforward. Furthermore, what one person perceives to be the truth can be very different to what another person perceives to be the truth. Specific techniques that can be used to improve digital literacy and boost resilience to misinformation include misconception-based learning and 'inoculation'[1]. Such techniques aim to give people a better understanding of common strategies used in spreading misinformation, thereby increasing their capacity to recognise and resist misinformation when exposed to it.

Public health actors have a major role to play in addressing the issue of vaccine misinformation, potentially in three main areas. Firstly, they are the main source of evidence-based information about vaccines and national immunisation programmes. Through their communication channels (see, for example, https://vaccination-

[1] In this context, 'inoculation' is a pre-emptive action that warns people in advance about how misinformation is used, thereby giving them the ability to 'resist' such information should they be exposed to it in the future.

info.eu/en/about-us), public authorities seek to develop vaccine literacy among the general population. They are also a source of expertise for health professionals, who use the tools and resources of public authorities to support their interactions with patients.

Secondly, public health authorities can monitor public discourse about vaccination to identify narratives that can affect vaccination willingness and uptake. Given the quantity of information (and misinformation) circulating, such monitoring needs to involve automated techniques, from simple data mining by the use of algorithms and keywords to more complex, automated tools that use artificial intelligence and machine learning. Public authorities can also collaborate with major social media platforms in their efforts to monitor online misinformation.

Thirdly, once misinformation is identified, public authorities can play a role in responding to it and preventing its further spread. Evidence suggests that the composition of messages intended to correct vaccine misinformation should follow the same principles as general vaccination communication techniques. Importantly, national authorities need to be present in major social media spaces, where misinformation may be spread. In designing messages intended to counter misinformation, tailored approaches may be most effective in reaching population groups that are particularly susceptible to misinformation. Corrective information in response to misinformation claims must come from trusted sources, so national authorities can consider cooperating with opinion and community leaders and other influential persons in spreading the message to given population groups.

Data from the six participating countries indicate that there are notable differences in the extent to which national public health authorities have committed resources to identifying and engaging with misinformation. Consequently, the format and breadth of monitoring activities they use varies greatly. Only the Netherlands report using continuous and automated social media monitoring tools, while some other countries report monitoring on a more ad-hoc basis without the use of dedicated tools. Some interviewees highlight the limited resources available to them for misinformation monitoring. Sometimes this task is under the jurisdiction of other public authorities, for example those responsible for tracking mis- and disinformation across many other domains for reasons of national security.

To conclude, this study shows that even among the six participating countries, approaches to countering vaccine misinformation vary substantially. Further, there is little monitoring and evaluation of interventions being conducted. National public health authorities may therefore want to consider assessing the adequacy of their capacity for monitoring misinformation circulating online, and to evaluate their communication efforts to counter misinformation. It would be beneficial if the findings from these efforts were shared with other relevant stakeholders within and between the countries in order to facilitate actions that are both evidence-based and coordinated.

1. Introduction

1.1 Vaccine misinformation and disinformation

False and misleading information, also known as misinformation, has, in recent years, taken an increasingly prominent space in the media landscape. The spread of misinformation has been facilitated by a rise in the use of online discussion fora and social media platforms, which allow it to travel faster and wider than ever before. Misinformation can be found in relation to numerous topics but is especially noteworthy – and dangerous – in areas of public concern such as politics and public health. A particular point of concern is misinformation involving vaccines and vaccination policies, because of its potential impact on vaccine uptake.

Many studies have explored the persuasive effects of online vaccine misinformation and found that exposure to it increases vaccine hesitancy[2] and negatively affects vaccine acceptance levels [1–5]. Vaccine hesitancy has been recognised as a major global health problem: in 2019, the World Health Organization (WHO) placed it on their top 10 list of global health threats, and stressed the need for countries to accelerate their efforts to tackle the issue [6].

The most infamous example of vaccine misinformation is the suggested link between the Measles-Mumps-Rubella (MMR) vaccine and autism, first made in 1998. While numerous subsequent studies have since confirmed the absence of such a link, and the original study was later retracted [7] by the journal that published it, the myth of vaccines causing autism has survived and continues to be circulated within groups opposed to vaccination [8].

It is important to stress there is a difference between vaccine misinformation and vaccine disinformation. Vaccine disinformation refers to the deliberate spread of knowingly false information, while vaccine misinformation is concerned with misleading content and the establishment of flawed causal links between facts but without obvious intent to harm. It is possible for disinformation to become misinformation and vice versa.

1.2 COVID-19 vaccine misinformation

At the time of writing, the world remains in the grip of the COVID-19 pandemic, and countries are rolling out their vaccination campaigns. The pandemic has provided a prime example of how easily misinformation can spread online. In the period since the pandemic started in early 2020, a flood of false claims has been produced about a wide range of issues, from the origins of the disease itself to the vaccines now on the market. Misinformation about potential COVID-19 vaccines started to spread even before any had been developed [9].

Among the many COVID-19 vaccine misinformation narratives that have been circulating are claims that the pandemic is a cover for a plan to implant trackable microchips, and the suggestion that the pandemic has been 'made up' so that people will take a vaccine that 'will bring money and corruption into the already full pockets of some'.[3] Another noteworthy example is a 26-minute video 'documentary' published in 2020, titled 'Plandemic'. Before the video was removed from YouTube shortly after being released, it had reached eight million views on the platform.[4] Such examples are being used, by individuals and organised groups, to oppose COVID-19 control measures and vaccination efforts.

The complexity and depth of COVID-19 vaccine misinformation have been amplified by general misconceptions surrounding the disease and a lack of long-term safety data of the newly developed vaccines. COVID-19 offers a unique insight into how rapidly vaccine misinformation can spread and why it is necessary to counter it quickly and effectively. Addressing vaccine misinformation has become an essential part of many COVID-19 vaccination campaigns.

As additional COVID-19 vaccines are expected to be authorised in the coming months and years, misinformation concerning existing and new vaccines is likely to continue evolving. Some of the current uncertainties regarding safety signals in relation to specific vaccines and the subsequent analysis of their risk-benefit profile may also give rise to increased misinformation. It is not yet clear how this will impact the uptake of COVID-19 vaccines. However, reduced vaccine confidence could make it more difficult to effectively fight the disease [10–13]. Additionally, it is conceivable that current narratives involving COVID-19 vaccines will influence how people

[2] Vaccine hesitancy is defined here as 'a behaviour, influenced by a number of factors including issues of confidence (e.g. low level of trust in vaccine or provider), complacency (e.g. negative perceptions of the need for, or value of, vaccines], and convenience (e.g. lack of easy access)'. [Source: Larson HJ, Jarrett C, Eckersberger E, Smith D, Paterson P. Understanding vaccine hesitancy around vaccines and vaccination from a global perspective: A systematic review of published literature, 2007–2012. 2014. *Vaccine*. 32: 2150-2159]

[3] See the narratives described: https://www.bbc.com/news/52847648

[4] A summary of the film's plot and details of its reception are available on Wikipedia: https://en.wikipedia.org/wiki/Plandemic

perceive vaccines more generally. There is therefore a need for countries to understand how such narratives develop and spread, and to have evidence-based tools available that can effectively counter them.

1.3 Responses at the EU level

In 2018, the European Commission (EC) published a report on the State of Vaccine Confidence in the EU, revealing large variations in public perceptions regarding the importance, safety, and effectiveness of vaccination [14]. Subsequently, in December 2018, the European Council called for stronger European cooperation against vaccine-preventable diseases [15]. Specifically, the Council Recommendation stated that, 'The rapid spread of misinformation through social media and by vocal anti-vaccination activists has fuelled misconceptions that are shifting the public focus away from the individual and collective benefits of vaccination and the risks posed by communicable diseases and towards increased distrust and fears of unproven adverse events.' On this basis, the Council directed ECDC to 'counter online vaccine misinformation and develop evidence-based information tools and guidance to support Member States in responding to vaccine hesitancy, in line with the Commission Communication on tackling online disinformation'.[5] This report is based on work that is part of the response to that call.

Work in this area continued with the first Global Vaccination Summit, convened in September 2019 by the European Commission and in cooperation with WHO [16]. The Summit participants, including policymakers, scientists, clinicians, and patients raised their concerns over declining vaccination rates and decreasing public confidence in vaccinations.

The advent of the COVID-19 pandemic in early 2020 prompted the EC to stress again the need to counter dis- and misinformation. In summer 2020, the EC published a communication on COVID-19 disinformation and announced an adoption of a European disinformation and monitoring plan, implemented jointly with several social media platforms.[6] This has become especially relevant in the context of the COVID-19 vaccines, which were, at that time, still under development. While an updated version of the State of Vaccine Confidence in the EU, also published in 2020, suggested that public confidence in the safety and importance of the seasonal influenza vaccine had increased markedly in most EU countries since 2018 [17], other work at that time indicated there was uncertainty in many people's minds about whether they would be willing to take a future COVID-19 vaccine [18, 19]. However, confidence in the COVID-19 vaccines increased markedly once they became available and were shown to be safe and effective, with the proportion of respondents across the EU saying that they would 'never' receive the COVID-19 vaccine estimated at just 9% in May 2021 [20]. Collectively, this demonstrates how perceptions about vaccines – influenced by misinformation in addition to other factors – can vary both between vaccines and over time.

1.4 Study goals and objectives

While online vaccine misinformation has been recognised as an issue that leads to increased vaccine hesitancy, there is relatively limited knowledge about the vaccine misinformation landscape in Europe. Such a knowledge base is needed to enable countries to design effective strategies for countering it.

This study, therefore, set out to enhance the knowledge base by exploring:

- The main sources of online vaccine misinformation in the EU/EEA;
- The evidence base for how to counter online vaccine misinformation;
- Current strategies used by selected national public health authorities in the EU/EEA and other organisations to counter online vaccine misinformation; and
- The training needs of national public health authorities in the EU/EEA for how to develop effective strategies for countering online vaccine misinformation.

The findings will help ECDC develop a training package for EU/EEA national public health authorities on countering online vaccine misinformation.

[5] European Council. Council Recommendation of 7 December 2018 on strengthened cooperation against vaccine-preventable diseases. Official Journal of the European Union, 2018/C 466/01. Available at: https://eur-lex.europa.eu/legal-content/GA/TXT/?uri=OJ%3AJOC_2018_466_R_0001

[6] See communications of the EC here: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020JC0008

2. Methodology

This study applied a mixed-methods approach consisting of a combination of qualitative and quantitative research methodologies. The following data collection methods were used:

- A scoping review of academic and grey literature describing existing efforts aimed at countering online vaccine misinformation;
- Interviews with representatives of pan-European and global organisations involved in countering vaccine misinformation;
- Interviews with representatives of the national public health authorities from six selected European countries (Estonia, France, Germany, the Netherlands, Spain, and Romania) who were responsible for countering online vaccine misinformation; and
- A social media analysis in the six participating countries.

The interviews and the social media analysis were used to develop country case studies, which are referred to throughout this report.

Note that this study did not attempt to distinguish between dis- and misinformation, as it was not always possible to establish with certainty the underlying intent of the analysed narratives.

The focus of this study is misinformation relating to vaccination against **measles (in combination with mumps and rubella), HPV, influenza, and COVID-19**. The study team's approach regarding COVID-19 vaccine misinformation was different from that for the other vaccines. Given that this study commenced early during the COVID-19 pandemic, no vaccine was available at the time of data collection. Despite that, even non-existent COVID-19 vaccines were subjected to an avalanche of speculative, often misleading, claims that could not be effectively countered with scientific evidence. Therefore, rather than exploring examples of COVID-19 misinformation-countering techniques, the study team focused on exploring COVID-19 misinformation more generally, along with misinformation-countering techniques applied to other vaccines. Thus, the identified experiences with misinformation for measles, HPV, and influenza vaccines may inform possible communications approaches regarding COVID-19 vaccines.

2.1 Literature review

A scoping review of academic literature aimed at identifying strategies in countering online vaccine misinformation was conducted. In addition to published academic sources, grey literature published by relevant stakeholders involved in countering vaccine misinformation was reviewed.

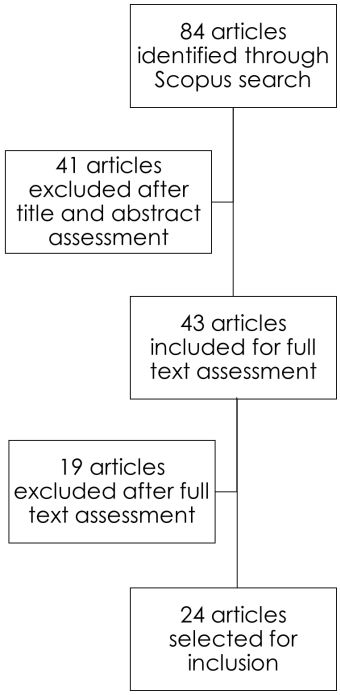
The initial search for academic literature was performed using the Scopus database in August 2020 using the following search teams:

> (TITLE-ABS-KEY (vaccin* AND misinformation) AND TITLE-ABS-KEY (counter*) OR TITLE-ABS-KEY (combat*) OR TITLE-ABS-KEY (strateg*)) AND (LIMIT-TO (PUBYEAR , 2010- 2020))

In total, 84 academic publications were identified and extracted for further assessment. After the title, abstract and full-text assessment, 24 articles were selected for inclusion in the literature review (see Figure 1).

The grey literature included publications by academic researchers as well as policy, non-governmental, and multilateral organisations. The search for grey literature occurred iteratively throughout the study and was non-systematic.

Figure 1. Academic literature assessment



Additionally, relevant publications on experiences with countering misinformation from the fields of climate science and genetic engineering in agriculture were searched in order to identify potentially transferable measures that could be applied to tackling vaccine misinformation. The search for this type of evidence was not as comprehensive as the one described earlier: only the best matching results were extracted and analysed. The sources of information included:

- Academic literature (searched in Scopus): keywords similar to those described above with keyword (vaccin* misinformation[Title/Abstract]) replaced by: (climat* misinformation[Title/Abstract]), (GMO* misinformation[Title/Abstract]).
- Grey literature (searched via Google): publications of (international and European) organisations providing guidelines for tackling misinformation in the field of climate change and genetic engineering in agriculture.

No relevant publications from the field of genetic engineering in agriculture were discovered. In the field of climate science, 42 relevant articles were identified, some of which also matched the inclusion criteria for the core search on vaccine misinformation literature.

2.2 Stakeholder consultations

The stakeholder consultation consisted of 1) interviews with representatives of national public health authorities involved in countering online vaccine misinformation in six selected European countries; 2) interviews with pan-European and global organisations involved in countering vaccine misinformation.

For the interviews with the national public health authorities, the following countries were included: Estonia, France, Germany, the Netherlands, Romania, and Spain. The aim was to reflect both the geographical diversity of the EU but also the contextual differences in attitudes towards vaccines, as well as the anticipated richness of the local misinformation landscape.

For every selected country, a national authority responsible for vaccine communication was identified. Using ECDC's Coordinating Competent Bodies structure (https://www.ecdc.europa.eu/en/about-us/governance/competent-bodies), people who may be involved with handling vaccine misinformation were identified and invited for semi-structured interviews with the study team. Each of the authority representatives was then asked to identify other relevant country stakeholders dealing with vaccine misinformation. Where such stakeholders were identified, the study team invited those stakeholders for a similar interview. For each country, one or two interviews were held.

The study team identified several key stakeholders involved in countering vaccine misinformation on a European level. These stakeholders were also invited for a semi-structured interview. They received the interview questions (available in Annex 2) and information about the study before their interviews.

2.3 Social media analysis

To identify sources of online vaccine misinformation, a social media monitoring and analysis was performed. The main language spoken in each study country (Estonian, French, German, Dutch, Spanish, and Romanian, respectively) was selected and combined with each of the chosen diseases (HPV infection, measles, influenza, and COVID-19). This resulted in 24 disease- and country-specific datasets.

Tool used
The social media listening tool Awario was used to monitor and analyse social media content in the form of tweets, news, blogs, and websites. Videos published on YouTube were directly identified and analysed, since Awario and other available social media tools were unable to process YouTube videos.

Time period
The social media analysis covered a period of three months, from 20 June to 20 September 2020. This timeframe comprised part of the period between the first and second waves of the pandemic in the selected countries. In addition, the development of COVID-19 vaccines and related clinical trials became a significant issue in the daily news. However, no COVID-19 vaccine was yet available, which meant that the discussions in the media were about hypothetical and as yet non-existent products.

Media formats
In this study, media data in all formats, including text messages, posts, articles, images, videos, and combinations of those formats, were analysed.

Keywords
A set of keywords for use in Awario was developed in the main language of each of the participating countries, concerning vaccines (seven keywords), effects and side effects (32 keywords), and terms used to describe each of the diseases of concern in the study (10 keywords in total)[7]. Those keywords were used in different combinations by use of the 'AND' function.

On YouTube, the search terms had to be limited to the disease and the term 'vaccine'/'vaccination'. e.g. 'measles' AND 'vaccine'/'vaccination.

Data extraction
Each search among tweets, news, blogs, websites, and YouTube videos resulted in datasets of different magnitude (e.g. from five posts regarding measles in Estonian to 4 881 messages in Spanish regarding COVID-19), from which the data containing misinformation were identified. Misinformation was identified as such if the study team considered the content demonstrably misleading or if it was seen to be based on the presentation of causal links that are contradictory to the prevailing scientific consensus at the time of the study. The classification was applied to any information displayed on the analysed source page. As acknowledged in the Limitations section below, this approach relied on subjective interpretation of the content, and other researchers may have categorised some of the materials in a different way.

To keep the analysis feasible, it was decided to limit the maximum number of analysed posts to a sample size of 100 tweets, news, fora, and blogs per disease per country, and a maximum sample size of 50 YouTube videos per disease per country. Where there were more than this number, a systematic sampling of the posts for analyses was used. For example, when there were 500 tweets or news items per disease per country in total, every fifth post was selected; while if there were 500 YouTube videos, every 10th video posted was analysed, thereby achieving a sample of 50. The total number of posts, articles, and videos that included vaccine misinformation was extrapolated based on the proportion in the reviewed sample relative to the number in the entire country dataset.

For tweets, news, blogs, and websites, the relevance and impact of the individual posts were estimated based on the metric 'Reach'. The Reach figure was calculated based on various metrics, depending on the online platform:

- Twitter: the follower count of the post's author combined with the number of likes, comments and retweets.
- YouTube: the 'view' count at the point of study time.
- News, blogs, and web articles: an estimated figure of daily website traffic (provided by the social media listening tool).

All data (when available) were ranked based on this Reach metric. All the sources that were analysed for this report can be made available upon reasonable request.

[7] The key words are available from ECDC on reasonable request

For each country and disease, the post with the highest recorded 'Reach' (based on the Reach metric of Awario) was analysed according to:

- The source – i.e. who was spreading misinformation;
- The topic – i.e. what was the misinformation about; and
- The narrative – i.e. what was the story-telling process and in which manner and tone of voice it was communicated.

3. Findings of country case studies

This section presents the findings of the social media analysis and stakeholder consultations for each case study country. The national experiences described in this section illustrate some of the measures aimed at countering vaccine misinformation being implemented in these countries by national authorities. However, the measures listed may not be comprehensive, as the responsibility may be shared between various bodies in some countries, not all of whom may have been consulted for this study.

3.1 Social media analysis

Within the time frame of the three-month data collection period, the online media output (covering tweets, news articles, blogs, websites, and YouTube videos) was analysed in the main language of each of the six case study countries. The analysis was based on the selected diseases – measles, influenza, HPV infection, and COVID-19 – and keywords as described in the methodology section. Material was classified as misinformation as per the definition of misinformation provided in the methodology section. Table 1 presents the number of online media outputs that were identified and analysed per country and disease area, with specification of the share of misinformation contained therein.

Table 1. Overview of analysed online media outputs per disease area and country

Country[8]	HPV		Influenza		Measles		COVID-19		Total	
	Posts	MI (%)	Posts	MI (%)	Posts	MI (%)	Posts	MI (%)	Posts	MI (%)
Estonia	6	2 (33%)	22	0 (0%)	5	3 (60%)	41	2 (5%)	74	7 (9%)
France	118	14 (12%)	535	77 (14%)	246	18 (7%)	1 518	88 (6%)	2 417	197 (8%)
Germany	147	5 (3%)	733	23 (3%)	351	25 (7%)	2,067	156 (8%)	3 301	209 (6%)
The Netherlands	85	6 (7%)	111	5 (5%)	100	4 (4%)	882	123 (14%)	1 178	138 (12%)
Romania	55	12 (22%)	295	40 (14%)	43	8 (19%)	641	69 (11%)	1 034	129 (12%)
Spain	210	4 (2%)	1 159	118 (10%)	445	9 (2%)	4 881	58 (1%)	6 695	187 (3%)
Total	621	43 (7%)	2 855	263 (9%)	1 190	67 (6%)	10 030	496 (5%)	14 699	867 (6%)

MI = misinformation posts

The **proportion of misinformation** across all channels and diseases in all six case countries lies between 3% (Spain) and 12% (the Netherlands and Romania). This suggests that misinformation makes up a relatively small but not insignificant part of all social media postings regarding vaccines and vaccine-preventable diseases in all of these countries. The share of misinformation across the different diseases is likewise similar, ranging from 5% (COVID-19) to 9% (influenza). However, since the number of postings about COVID-19 was much higher than for the other diseases (68% of all the postings identified), this translates into a much greater quantity of misinformation.

The types of **narrative** encountered in the analysed pieces of misinformation were similar across all case study countries. Typically, narratives centred on allegedly vaccine-injured children and severe adverse effects of vaccinations, or on conspiracy theories (e.g. nefarious relationships between vaccinations and totalitarian governments, 5G technology or profit-making 'Big Pharma'). Some of the analysed pieces of misinformation from Germany also warned against supposed permanent and irreversible modification of the human genome due to the mRNA technology on which some of the novel COVID-19 vaccines are based.

The pieces of information analysed were from both individual and organisational sources. In France, Germany, and the Netherlands our analysis found several sources that, during the analysis period, posted multiple pieces of misinformation. These sources included individuals as well as websites of organisations or movements that are vocally opposed to vaccination or that purport to counterbalance 'mainstream media'.

Some of the pieces of misinformation analysed had very significant Reach. Among the analysed YouTube videos that contained misinformation, some had several thousand views. Likewise, tweets containing misinformation were identified that had reached hundreds or even thousands of other accounts. It is worth noting the role

[8] Note that, due to methodological limitations associated with the Awario tool, information pieces could not be unambiguously assigned as having originated in the case study countries. Rather, they were published in the main language of those countries. It is possible that posts in Spanish originated in other Spanish-speaking countries (for example in Latin-America) and that French posts include those from other French-speaking countries or regions (including Canada and parts of Africa), or even from countries where these languages are not widely spoken.

played here by the source of the (mis)information. One of the analysed YouTube videos, which had achieved a high number of views, was uploaded by an influencer with his own YouTube Channel. In this video, the influencer, together with three doctors, casts suspicions on the effectiveness and safety of various COVID-19 measures, as well as on COVID-19 vaccines[9]. This case illustrates how the use of health professionals using medical jargon may give credibility to any claims made, even when their specific expertise may not be in the control of infectious diseases. Further, their contribution to the debate may serve to create a false impression about a lack of scientific consensus on the topic.[10]

The share of misinformation found on YouTube was higher than that jointly on other types of media in all case study countries, except for Spain (Table 2). New videos containing vaccine misinformation were uploaded on YouTube with considerable frequency: in Germany alone, during the study time frame, 351 new videos about then not-yet-approved COVID-19 vaccines were posted, of which 20% contained misinformation.

Table 2. Share of misinformation on YouTube compared to all online media channels

Country	YouTube		Other media channels	
	Posts	**MI (%)**	**Posts**	**MI (%)**
Estonia	5	4 (80%)	74	7 (9%)
France	25*	14 (56%)	2 417	197 (8%)
Germany	409	83 (20%)	3 301	209 (6%)
The Netherlands	39	13 (33%)	1 178	138 (12%)
Romania	172	37 (22%)	1 034	129 (12%)
Spain	234	5 (2%)	6 695	187 (3%)
Total	**884**	**156 (18%)**	**14 699**	**867 (6%)**

3.2 Outcomes of stakeholder consultations

Estonia

The Estonian Health Board (EHB) is responsible for carrying out the national immunisation programmes in Estonia. It is also responsible for vaccination monitoring and the collection of country-wide statistics. While Estonian is the official national language, there is a large Russian-speaking minority in the country: about 30% of the population speak Russian as their main language. All communications of the EHB are therefore produced in both Estonian and Russian to ensure access to information.

The EHB recognises the issue of online vaccine misinformation and works actively on the subject. The agency's communications department implements continuous albeit non-systematic monitoring of the (social) media landscape, particularly online groups and pages, to identify and respond in a timely fashion to vaccine misinformation. The team is also responsible for the upkeep of the national vaccine information website (www.vaktsineeri.ee). Since the communication officers do not have in-depth technical knowledge of different aspects of vaccination, they are supported by infectious disease and immunisation experts working across the organisation. The communications team reacts immediately to misinformation claims and is the first point of contact for those who want to get in touch with the EHB about this issue. To streamline the responses of the communications team, EHB experts have developed a guidance document containing standard responses to frequently asked questions and common misinformation claims. The Health Board experts support the communications team with the development of more tailored, targeted responses to specific misinformation claims online. The communications team posts expert responses to pieces of misinformation (in the form of screenshots) on their (social) media accounts, which attracts a lot of public attention and has improved the overall visibility of the organisation.

Besides reacting to emerging misinformation claims, the EHB and its communications unit proactively develop plans and strategies for potential future spread of misinformation. For example, at the time of our interview preparatory work was ongoing for the then-future COVID-19 vaccines. At this time, the EHB was setting up a Competency Centre to support the communications team in responding to possible misinformation claims and all general concerns about such a vaccine. The EHB also underlines the need for health professionals to understand and apply techniques for countering misinformation. They particularly specify those health professionals who have a direct role in administering the vaccines. While the EHB feels sufficiently acquainted with online vaccine

[9] https://www.youtube.com/watch?v=eD1gth-iplw

[10] The invited panellists in the video were two general practitioners and a dermatologist, all of whom were known critics of the COVID-19 policies of the country concerned.

misinformation issues and their countermeasures, limited resources are a major obstacle to advancing their efforts on the matter.

Since Estonia is relatively small, all major local online vaccine misinformation outlets are known to and closely monitored by the EHB. According to the EHB, a group that is particularly prone to spreading vaccine misinformation in Estonia includes those who identify as 'parents of children damaged by vaccines'. The group has its own association, website, and Facebook group.

While major misinformation outlets are known and monitored, the EHB experts emphasise that there is a body of misinformation in the Russian language that is not routinely monitored. Currently, the Health Board focuses on misinformation in Estonian, which still makes up the larger share of vaccine misinformation in the country. Given its limited resources, the EHB cannot monitor and respond to misinformation claims in Russian to the same extent as they do in Estonian.

Although the EHB experts voiced concern over the spread of misinformation in Russian in the country, the extent to which Estonia is affected by vaccine misinformation from the Russian Federation is not clear. Our social media analysis only focused on misinformation spread in Estonian and is therefore not able to shed further light on this issue. It is also not clear what impact vaccine misinformation in Russian may have on rates of vaccine uptake in the country. The majority of Russian-speakers live in the region of Tallin and the eastern border regions (around the city of Narva). While the vaccination rates in Tallin are some of the lowest in the country, in Narva and other border regions they are above the national average. Our interviewee from EHB suggests that this may signify that vaccine trust may be high in some Russian-speaking areas of the country.

Spain

In Spain, the Ministry of Health is responsible for the implementation and monitoring of national immunisation programmes. The vaccination rates are high, which representatives for the Ministry explained are due to a high level of public trust in the medical establishment, in particular the health workforce. The Ministry of Health deals with communication around vaccinations in Spain. Given that vaccination rates are high, at the time of the interview the Ministry did not see a special need to dedicate resources to address vaccine misinformation. While it does not employ a specific strategy for countering misinformation, the Ministry does use various measures for addressing the issue. This involves vaccination experts as well as the press department.

The Ministry applies a predominantly reactive approach to online vaccine misinformation. Particularly when a piece of misinformation becomes widespread, the Ministry responds by debunking and publishing correct information via their website or, in urgent cases, holding press conferences to address the issues. The Ministry also works on search engine optimisation (SEO) to ensure that official information sources are easy to find and widely accessible to the public.

The Ministry has several mechanisms for communicating with the public and to respond to people's requests. On occasion, it has engaged in direct conversation with known anti-vaccination advocates. However, the Ministry does not directly respond to online vaccine misinformation on social media, nor does it report misinformation to the platforms.

Outside of the Ministry, online vaccine misinformation is, to some extent, monitored by a special national security taskforce that works on addressing mis- and disinformation on various subjects. The taskforce approaches the Ministry on specific vaccine-related subjects, and the Ministry supports the taskforce with debunking and providing accurate information.

Germany

In Germany, the Standing Committee on Vaccination at the Robert Koch Institute (RKI) is responsible for vaccination monitoring. According to the stakeholders interviewed, RKI itself does not systematically monitor online vaccine misinformation. RKI experts therefore rely on insights into the misinformation landscape gathered by other organisations and experts. However, the issue has received more recognition recently, particularly with the rapid spread of online misinformation regarding COVID-19 and (at the time the interviews were conducted) any potential vaccine against it.

The RKI applies a 'preventive' approach to countering vaccine misinformation, which focuses on effective and clear vaccine communications. The organisation focuses on providing evidence-based information about vaccine safety, effectiveness and the importance of immunisation in general, rather than responding directly to online misinformation. In their vaccine communications efforts, the RKI collaborates with several stakeholders, particularly academic experts, who support the Institute by sharing knowledge and advising on their communication approach. In particular, the Institute focuses on supporting health professionals in disseminating evidence-based information and recommendations through, for example, the use of smartphone applications and leaflets.

According to the RKI, there are many groups and individuals in Germany spreading vaccine misinformation. These include practitioners and followers of alternative medicine, conspiracy theorists, etc. These groups also create alliances with other stakeholders, such as right-wing political movements and other groups opposing current

policies in different spheres. The RKI experts explained during the interview that the target audience for those who spread vaccine misinformation online has widened to include the general public, thereby moving beyond specific population groups.

The RKI experts underlined the need for the organisation to delve deeper into countering online vaccine misinformation, particularly to further support national health professionals in this task through the provision of training and additional resources. The Institute highlights that health professionals should become more aware of specific communication techniques that have been shown to be effective in addressing vaccine misinformation.

France

Santé Publique France (SPF), the French national health agency, is the organisation implementing infectious disease control and surveillance in the country. The agency deals with vaccine communications, including monitoring and responding to online vaccine misinformation.

SPF conducts monitoring of the online information landscape around vaccines in France. Monitoring of social media is not a priority area of the agency. At the same time, the SPF representative who was interviewed stressed that misinformation is also present in the press and other online outlets. The Government Information Service is responsible for monitoring French online media regarding any misinformation on COVID-19 itself or on vaccines that protect against the disease.

SPF considers itself aware of the main sources of online misinformation in the country: those are four to five large anti-vaccination groups spreading content through often-closed groups on social media platforms such as Twitter and Facebook. The agency actively monitors the main channels spreading misinformation. While vaccine misinformation is usually shared within anti-vaccination communities, the agency notices similar narratives in other types of (social) media discussions, even those for which health and vaccines are not the central subjects. Once a piece of misinformation becomes widespread (i.e. it enters mainstream media and receives press coverage), SPF responds by producing communications around the matter. The approach is to produce evidence-based and emotionally neutral information. Smaller, less apparent misinformation claims are not picked up by the agency.

Since SPF does not have the resources to dedicate to continuous online misinformation landscape monitoring, they seek partnerships with external parties. For example, it collaborates with Twitter in debunking misinformation and forwarding readers to trustworthy sources of information around vaccines. The agency also works on search engine optimisation (SEO) to ensure that the public has direct access to trustworthy sources.

SPF stresses that although there is attention and understanding regarding how to respond to vaccine misinformation, communications and health professionals need more resources and guidance on the matter.

The Netherlands

In the Netherlands, the National Institute for Public Health and Environment (RIVM) is responsible for national immunisation programmes and vaccine communication. To support national efforts in countering vaccine misinformation, the government of the Netherlands has, since 2018, supported a special 'Misinformation Thinktank', which comprises multidisciplinary experts such as physicians, scientists, and public health and communication specialists, as well as a representative from the Ministry of Health, Welfare, and Sport.

The RIVM puts substantial efforts into countering online vaccine misinformation. It has adopted a strategic approach, which includes routine (social) media monitoring and an extensive presence on various social media platforms. The monitoring of (social) media is carried out by a team of four people. Apart from vaccine misinformation, the team also actively monitors other topics of public discourse relevant to the organisation's mandate. It uses Coosto, an online social media monitoring tool, to produce daily monitoring reports across the main social media platforms, except for YouTube and WhatsApp. The RIVM is active on Facebook, LinkedIn, and Twitter, with a more active presence on the latter platform as it considers the discussions there to be more 'genuine' (meaning that those engaged in discussions are open to adjusting their positions) and less characterised by entrenched opinions. The RIVM's current approach to social media is to react only to what it perceives as legitimate vaccine-related questions, without getting heavily involved in discussion. The RIVM routinely monitors the major accounts and pages that it knows spread misinformation. However, it has become increasingly challenging to identify and monitor such sources, as the number of people involved in online vaccine misinformation discussions is growing. The RIVM's decision on whether to respond to online misinformation is informed by source and reach (e.g. how widely can this source spread the specific piece of misinformation?).

The RIVM's approach to countering online vaccine misinformation focuses primarily on what is termed 'inoculation' against misinformation: they aim is to provide the public with accurate evidence-based information in the hope of making people less susceptible to misinformation when they come across it. RIVM uses big data analytics to understand what type of vaccine information people are searching for online. In addition, the RIVM analyses the content of major vaccine-critical websites. Together these insights help experts produce accurate, relevant, and easily accessible (thanks to search engine optimisation) online content that counters claims made by sources spreading vaccine misinformation.

Separate to the efforts of the RIVM, experts working with the Misinformation Thinktank react independently to public discussions concerning vaccination in the country. In this, its members operate in their personal capacity, i.e. not being affiliated with any organisation. The thinktank is coordinated by the Ministry of Health, but its members do not receive remuneration for their involvement. There is also no set, coordinated response strategy, although members of the thinktank have participated in a workshop to learn about effective communication strategies.

The members of the thinktank mainly use their own social media accounts to counter vaccine misinformation. On occasion, the thinktank has worked with other organisations, such as the national Advertising Code Committee, to flag false or misleading content and promote correct information. Within the thinktank, there is also a representative from Facebook to discuss the role of the social media platform in countering misinformation.

A representative for the Ministry of Health, Welfare and Sport has underlined the importance of the independence of the thinktank. Thus far, the Ministry has primarily acted as a facilitator for the thinktank, but the thinktank is not in any way accountable to the Ministry. However, the COVID-19 pandemic and expected public debate about the uptake of COVID-19 vaccines raised the question as to whether the thinktank should become more structured in its operations, with greater involvement by the Ministry, in order to ensure a more aligned response between its members.

Romania

The National Institute of Public Health is the organisation responsible for carrying out immunisation programmes in Romania. The Institute is also responsible for vaccine-related communications.

Given the limited capacity of its communications unit, the Institute currently does not have a system for monitoring online vaccine misinformation. Information around vaccine communication (safety, effectiveness, etc.) is published through an online information portal for parents. The Institute also supports a Facebook group where experts can answer questions of the public. While the contents posted by the public or the experts in this Facebook group have not been assessed, it appears to have gained some level of popularity as the page currently has over 90 000 members.

The Institute sees a great need to become better trained in responding to online vaccine misinformation and to introduce a system for monitoring the online (social) media landscape. Currently, the Romanian public health authorities have neither the capacity nor the resources for dedicated efforts aimed at countering of online vaccine misinformation.

4. Thematic findings

This chapter contains a synthesis of findings of the literature review, stakeholder interviews, and social media analysis. The sources of individual findings are specified. The chapter has been structured thematically, aimed at providing insights into the problem of vaccine misinformation itself, the underlying issues, how it can be monitored online, and how it can be countered.

4.1 The problem of online vaccine misinformation

Sources

In discussing sources of online vaccine misinformation, one should distinguish between the 'originators' of misinformation and the platforms or networks through which it is spread. It appears that very little is known with certainty about the originators of misinformation: no studies from the literature review were identified that investigated which parties are responsible for *creating* misinformation. Interviewees similarly had little to no detailed insight into how, where, or why (online) vaccine misinformation emerges. Some believe that most vaccine misinformation originates in the United States. The evidence available to the study team, however, is insufficient to corroborate this. Some literature and several interviewees have also suggested sources within Russia as a point of origin for disinformation (i.e. misinformation with malicious intent). One study of vaccine-related posts on Twitter identified a large body of bots and trolls from within the country, spreading both pro- and anti-vax narratives [21]. By playing both sides of the argument, bots and trolls are amplifying their reach as well as attempting to take more effective control of the discussion. Bot accounts also post more often than non-bot accounts and use the large bot network to further spread messages. The present case study project did not provide any insight into why or how misinformation is created, as it is typically not possible to derive this from the data sources that were used for this study.

More is understood regarding how online vaccine misinformation spreads. Here, social media play a particularly important role. Numerous studies have analysed the spread of misinformation through social media platforms [1,2,21–32]. However, while social media drive the spread of misinformation, postings on social media are often fed by other types of media, such as anti-vax websites and news sites [23,29]. The social media analyses presented above illustrate what form vaccine misinformation may take in the participating countries, and how it spreads. In addition to the significant volume of misinformation accessible on public platforms and websites, it is known that much is shared in closed networks, such as closed online groups and chats, and these are not easily accessible to outsiders [30]. One study was identified that compared the depth of discussion and interaction between members of a small, closed group on Facebook versus followers of a large vaccine choice information page on the same platform [26]. The breadth and depth of discussion as well as the frequency of posts were all higher in the closed group, which also contained more misinformation.

Susceptibility to vaccine misinformation

Many people are, albeit to different degrees, exposed to vaccine misinformation: several studies also show that exposure to vaccine misinformation occurs across different demographic groups and that belief in misinformation is not limited to any particular group [1,2]. This is in line with the observations of interviewees. However, some studies identify specific groups as being at higher risk of being affected by misinformation. These include mothers, persons with lower numeracy skills, and ethnic minorities [1,29,33]. Individuals' belief systems, particularly their level of trust in science, government, and the media are also important predictors of susceptibility to misinformation. There is a greater tendency for people who believe in various sorts of 'alternative' information, such as alternative or traditional medicine and conspiracy theories, to encounter, believe, and share vaccine misinformation [1,3,23,24]. This observation is shared by the interviewees.

Overall, there is a substantial body of evidence suggesting that exposure to vaccine misinformation leads to decreased vaccination intent [1–5]. One study found that parents who are frequently exposed to misinformation are less likely to vaccinate their own children [5]. Studies also highlight the prolonged effect of exposure to vaccine misinformation: misinformation claims can remain in the memory months after exposure to the original items of misinformation [4,5].

Narratives

Generally, vaccine misinformation narratives online are similar to the typical narratives used by anti-vaccination communities. Such narratives have been explored in many studies, and are not further discussed here in detail [18,25,26,28]. Nonetheless, several main narratives can be highlighted, including but not limited to:

- Calls for the public to become 'informed' about vaccines, their ingredients, and associated risks;
- A focus on pharmaceutical companies' economic profits in connection with vaccination programmes;
- Highlighting the side-effects of vaccination and comparing those with disease incidence rates;

- Falsely presenting/overstating statistical data related to risks and adverse effects of vaccinations;
- Emphasis on allegations about mandatory vaccination and freedom of choice;
- Suggesting links between vaccination and autism or other diseases;
- Presenting conspiracy theories concerning vaccinations;
- Highlighting an apparent lack of scientific evidence regarding the efficacy and safety of vaccines; and
- Questioning the rapid development or improvement of vaccines.

While all of the above narratives may contain erroneous statements to a different extent, one needs to be careful in distinguishing general anti-vaccination narratives from misinformation claims. For instance, narratives linking vaccination to particular diseases or conspiracy theories will almost certainly contain misinformation, whereas narratives focused on adverse events and risks do not necessarily involve fallacious claims. Other narratives are rooted primarily in attitudes towards personal responsibility and rights and thus may not contain any misinformation at all. Some of the above-presented narratives have emerged or have been particularly evident in the context of the COVID-19 pandemic. These include narratives on suspect economic motives of industry, assessments of benefits versus risks, and conspiracy theories about governments' attempts to remove personal freedoms.

Interviewees pointed out that the types of narrative and message-framing involving vaccine misinformation may vary across belief systems. For instance, among those on the far right of the political spectrum, opposition to vaccination is commonly framed in terms of resistance to governmental infringement on civil liberties. This is evident in the context of the COVID-19 pandemic, where anti-vaccination narratives go hand-in-hand with resistance to recommendations regarding the wearing of face masks, physical distancing, and lockdown policies. In some other spheres, anti-vaccination narratives are more commonly linked to a belief in 'organic' remedies over ones rooted in medical science, as well as to distrust in 'Big Pharma'. Even though such groups, with otherwise very divergent belief systems, may not regularly interact with each other (in daily life or online), similar pieces of misinformation can spread rapidly through multiple, largely unconnected networks if the framing is adapted to its target audience. For instance, narratives centred on the mRNA-based technology underpinning some of the currently available COVID-19 vaccines have evolved in various ways. In some circles, these narratives are framed as elaborate pseudo-scientific treatises to convince readers that these vaccines will modify a person's DNA and cause serious health damage. In other circles, similar arguments involving the technology's presumed DNA-altering potential are used but, rather than dwelling on the health impacts, the suggestion is raised that 'globalists' are using the technology to further their agenda through population control. Even though both framings involve a suggested link between mRNA-based technology and cancer, one plays on the fear of modern medicine while the other plays on fears of big government and liberal ideology.

4.2 Understanding the underlying issues

Digital, health and science literacy

The results of the literature review, country case studies, and other stakeholder interviews show that vaccine misinformation is to a degree rooted in a lack of basic understanding of how vaccines work and are developed. This is also reflected in a more general lack of understanding of the scientific process. Several interviewees suggested that one of the challenges of communicating vaccine information is that many people have a poor understanding of the scientific process. This particularly refers to the evolving nature of scientific evidence and the need for health authorities and decision-makers to rely on incomplete information that can evolve or change over time. This has proven especially true with COVID-19. It is rare for the general public to be exposed to 'science in action' and to deal with the uncertainties of scientific evidence in the way it has been during the COVID-19 pandemic. Rather, people expect public health authorities – and politicians – to provide definitive answers and solutions. When responsible authorities are not able to clearly communicate to the general public what the basis for their decision-making is and how this has evolved over time, this can feed uncertainty, and through this the creation and spread of misinformation [33,34–36].

Misinformation tends to spread where information is lacking or incomplete, as this undermines trust in existing information systems and creates room for alternative sources and theories [28]. A lack of trust in the goodwill of public health systems and governments, which vaccine misinformation promotes, poses a critical challenge. This notion of distrust further polarises public discourse, not only about vaccines but also in many other spheres. This needs to be addressed by national health authorities as well as by other actors [31,33,36,37].

Over the last 30 years, scientists have generated a large body of information on vaccine safety, yet misinformation claims have gained popularity and are now shared by a significant subset of the population. It has become clear that simply publishing scientific evidence is not enough to affect people's understanding when there is so much contradictory information available. It is, to a large extent, up to the individual to distinguish between trustworthy and false information. In other words, today's public can choose what to believe. In a perfect world, this choice would be based on a critical assessment of the source, but studies show that various other factors,

particularly those pertaining to individuals' prior beliefs, influence the decision as to whether or not to trust a given piece of information [1,3,23,24].

Need for improving individuals' ability to critically assess information

While an individual's ability to critically assess online claims is one of the key factors for determining whether or not they accept misinformation, several studies indicate that many people do not have sufficient capacity in this area [4,5,33,38,39]. It is, therefore, crucial to use educational approaches to support people in identifying misinformation so they do not accept, respond to, or share it [33,39,40]. Some approaches for educational interventions to improve vaccine literacy include gamification, peer-to-peer learning, and learning through story-telling [41,42]. Exploring techniques for information assessment and verification was not the primary scope of this study. Nonetheless, based on the reviewed literature, two steps are found to be important: the assessment of the source of information, and the assessment of the presented evidence.

Assessing the source of information refers to an individual's ability to recognise whether the place of publication of the information piece is credible. The assessment of evidence refers to determining the scientific validity of the statements made. The literature offers some recommendations on how to assess evidence; for example, a study by Pineda & Myers (2020) provides guidelines to parents on assessing health-related websites [38]. These include assessing practical factors such as who are the sponsors associated with the site and whether their contact information is available, as well as a more complex critical assessment of the potential level of bias the website may express, whether scientific evidence is presented, and whether facts are distinguished from the writer's opinions.

When talking about the need to improve the public's assessment of information sources, it is crucial to highlight that the skill of critical thinking is required for assessing any piece of information [39,43]. It is also the basis for building trust in science, in public services, and in governments in general. Similarly, reflective and analytical thinking are associated with reduced susceptibility to vaccine misinformation [1]. The development of the capacity for critical thinking is a joint responsibility of many actors, but particularly those in the education system. With the emergence of COVID-19, the call for an expanded curriculum on critical thinking has become louder.[11]

Some climate science communications experts have also highlighted the importance of education in the development of critical thinking skills. They propose the application of misconception-based learning approaches in study curricula [44]. This type of learning involves teaching scientific concepts by studying misconceptions and how they distort science, or by applying the critical assessment of misinformation and techniques used to mislead the public. Studies have found that misconception-based learning leads to better and longer-lasting learning gains and improved critical thinking skills, while also being more engaging for students. Misconception-based learning may be a potent tool to improve critical assessment skills, which, in turn, could lead to the public becoming more resilient to vaccine misinformation. However, the application of such an approach is a task beyond the responsibilities of national health authorities or health communication scientists, as it requires the involvement of education system actors.

Role of stakeholders

As discussed in the previous chapter, digital, health and general science literacy are important factors that affect one's susceptibility to vaccine misinformation. Lack of critical thinking and understanding of science are structural problems that need to be addressed at various levels of society. While there is an inevitable information asymmetry between experts and the public at large, both the literature and interviewees stress that this should not prevent public health actors from addressing misinformation. The rise of misinformation has made clear that there is a need to evolve the ways in which public health authorities approach health communication. For example, medical research communities have called for improving communications of research results in a way that better matches the needs and expectations of the general public [1,45–47]. Many scientists today call on their peers to confidently express their scientific views online and in real life, and to be available to answer questions from the public. This can be done through, among other activities, collaborations with media outlets, publications of popular science articles, and press releases.

Reviewed literature highlights the role of health professionals and stresses that these remain the most trustworthy sources of health information for parents [2,4,5,23,45,48,49]. Some interviewees of national health authorities also highlight that they rely on the public's trust in health professionals. According to them, higher levels of trust reduce the spread of vaccine misinformation. It is therefore important for health professionals to disseminate evidence-based information about vaccination and vaccines, and that they are able to respond to misinformation claims both privately with their patients as well as in public (e.g. online) settings [2,4,5,23,45,48–50].

[11] See, for example: https://www.forbes.com/sites/colinseale/2020/04/10/the-case-for-critical-thinking-the-covid-19-pandemic-and-an-urgent-call-to-close-the-critical-thinking-gap-in-education/

Based on the analysis of the literature and the outcomes of the discussions with stakeholders, three options for action have been identified for national health authorities to address misinformation [18,24,30,31,33,36,40,51–55]:

- Firstly, national health authorities should be **the primary public source of evidence-based information about vaccines and national immunisation programmes**. Through their communication channels, national authorities seek to develop vaccine literacy among the general population. National authorities are also a key source of expertise for health professionals, who use appropriate tools and resources to support their interactions with patients.
- Secondly, national authorities can **monitor public discourse about vaccination** to identify narratives as well as any circulating misinformation that can affect vaccination willingness and uptake [33].
- Thirdly, once misinformation is identified, national authorities can play a role in **responding to it and preventing its further spread**.

Between the six analysed countries, there are notable differences in the extent to which national authorities have committed resources to identifying and engaging with misinformation. While some focus primarily on communicating correct information, others also actively monitor misinformation and react to it. The literature suggests that, in light of the significant amount of online vaccine misinformation being circulated, it is important for health authorities to place sufficient emphasis on monitoring and responding to misinformation [32,37].

Social media platforms can also act as key stakeholders in tackling misinformation. While platforms have not historically been eager to impose censorship on user-generated content, their stance has somewhat changed recently, further accelerated by the emergence of COVID-19 and the information crisis stemming from it. It is widely felt that social media platforms have a responsibility to remove mis- and disinformation claims that endanger public health, or at least that they should reduce exposure to such content [25,28,33,56]. Facebook now flags, and even actively removes, vaccine misinformation, and it also directs users to official resources when they search for vaccine information on the platform. Twitter and Instagram have also taken measures to limit the spread of misinformation by removing potentially harmful content. These moves are not without controversy, and interviewees emphasise that it should not be the role of national health authorities to engage in or contribute to censorship. Nonetheless, interviewees welcomed the platforms' increased efforts to combat the spread of misinformation. Social media platforms have also entered into various collaborations with national and international health authorities and have developed additional tools to ensure that users looking for vaccine-related information are directed to trustworthy sources [25,33,56].

4.3 (Social) media monitoring

As already discussed in various parts of this report, social media are major outlets of vaccine misinformation, and also provide the venue for a large proportion of ongoing anti-vaccine debates. For health authorities, understanding this discourse – on social media as well as in other media outlets – is crucial when designing effective communication messages and strategies to stop misinformation from spreading. Therefore, actively listening to the public discourse is key.

Many studies and policy publications call on national authorities to place more emphasis on the monitoring of misinformation [21,27,30,31,33,52,54]. Considering its scale, misinformation monitoring cannot be done by hand but needs to involve technology, starting from simple data mining by use of algorithms and keywords to more complex, automated tools that use artificial intelligence and machine learning techniques. The literature review and discussion with stakeholders identified several studies that use various forms of social media monitoring tools. Some of these are presented below. Note that inclusion in this list does not represent an endorsement of any particular tool.

CrowdTangle[12] is a media listening tool developed and hosted by Facebook, which enables users to 'track influential public accounts and groups across Facebook, Instagram, and Reddit, including all verified users, profiles, and accounts like politicians, journalists, media and publishers, celebrities, sports teams, public figures and more'. It does not provide access to content shared in private Facebook groups. Access to the tool is restricted to a limited set of eligible organisations, which include Facebook's own third-party fact-checkers, as well as academic researchers, journalists, and representatives of Facebook pages that generate content to the public. National public health authorities are possibly eligible under CrowdTangle's Academics & Researchers programme, but no information was available on whether any EU-based public health authorities currently make use of this software.

Hoaxy is a tool that works with Twitter platforms. Unlike other tools that track Twitter hashtags, Hoaxy tracks tweets that provide links to websites. Hoaxy is based on a 'source list', which is a list of website domains, and the tool tracks all tweets with a link to these websites. The source list of Hoaxy contains 120 low-credibility websites reported by expert journalists and seven well-known fact-checking websites in the United States. The use of Hoaxy was described in a study by Shao et al [54]. The study also uses a **Botometer** tool, which allows the

[12] Note that mention of any products or companies in this report does not imply endorsement by ECDC.

identification and classification of bot accounts. Botometer conducts classification by supervised learning, whereby tweets are assessed for a range of features such as network, temporal, language, and sentiment signals.

Sear et al. [32] identify and analyse the evolution of pages that spread COVID-19 misinformation on Facebook through the application of machine learning combined with human coding. Researchers initially manually identified vaccine misinformation-prone pages, from which an automatic snowballing approach was initiated to identify related pages. The collected data were then analysed using an unsupervised machine learning technique, Latent Dirichlet Allocation, to analyse the emergence and evolution of topics around COVID-19. While this example does not utilise a specialised tool for social media analysis, it shows that this type of data collection and analysis approach can be used for this purpose.

A study by Amith and Tao [57] proposes the use of a self-developed Vaccine Misinformation Ontology (**VAXMO**) tool to support the classification of identified misinformation claims according to frequent narratives used by anti-vaccination communities.

Other tools mentioned in the literature and by interviewees include **Socialbearing.com** (analysis of tweets) and **Facebook Graph API** for the monitoring and collection of misinformation data, as well as more widely used tools such as **ATLAS.ti** and the programming language 'R' for the analysis of collected data [28,30,50]. While the latter are not designed specifically for social media monitoring, they can be useful in storing information in databases and facilitating the categorisation and analysis of that information.

The literature also highlights the need for health authorities to work with major social media platforms in their efforts to tackle misinformation [31,33,56]. Although interviewees do not consider it appropriate for health authorities to report specific pieces of misinformation to platforms, as previously indicated, authorities can provide support to the platforms with issues such as the prioritisation of topics, fact-checking, and the development of response strategies. Health authorities can also flag broader developments to social media platforms and advise them to take appropriate actions in line with the platform's strategy for handling misinformation.

One significant issue is that a portion of anti-vaccine and misinformation debates take place in private Facebook groups and through other closed platforms, often with large numbers of highly engaged members. Some research shows that many undecided and hesitant parents join such groups in search of vaccine information [29]. The EU's General Data Protection Regulation does not permit the routine collection and use of personal information from EU citizens (including names, personal identifiers, contact information, and IP addresses), which means that authorities cannot gain access to these closed platforms or their content [58]. Nonetheless, authorities working to address online vaccine misinformation should at least be aware of them, and take them into account when designing debunking and inoculation strategies.

The format and breadth of monitoring activities employed by national health authorities vary greatly across the world and in Europe, as shown in the case studies. Among the country cases, only the Netherlands reports using continuous automated social media monitoring tools, while some others report monitoring on a more ad-hoc basis without the use of dedicated tools. Some interviewees highlight the limited resources available to them for misinformation monitoring. Sometimes this task falls under the jurisdiction of other public authorities, for example those responsible for tracking mis- and disinformation across many other domains for reasons of national security. International and multilateral organisations are also taking measures to monitor online vaccine misinformation. Within the EU, several initiatives exist, including the **European Digital Media Observatory**, **EUvsDisinfo** and **EU DisinfoLab**, which focus on monitoring and debunking disinformation claims. EUvsDisinfo focuses specifically on disinformation originating from sources within Russia.

The increasingly rapid spread of misinformation, sometimes referred to as an 'infodemic', is also of great concern to WHO, which has developed the concept of 'infodemic management'. To track and respond to misinformation regarding the COVID-19 situation, the WHO Information Network for Epidemics (EPI-WIN) works to monitor digital media across eight separate media platforms. WHO is also building an 'infodemic observatory' aimed at identifying so-called bots and trolls spreading mis- and disinformation. Furthermore, it is constructing a fact-checking database and a dashboard to geolocate misinformation. Currently, these efforts are primarily focused on COVID-19-related misinformation. The concepts and technology, however, also have wider applicability for any vaccination-related misinformation.

4.4 Strategies and techniques for tackling online misinformation

Strategies for tackling vaccine misinformation are, in many respects, similar to general vaccine communication strategies. The basis is the provision of correct, evidence-based, transparent, and timely information regarding vaccines, immunisation processes, and policies. In this study, general vaccine communication approaches were not explored in detail, as those have already been described extensively elsewhere. Instead, this study focused on identifying approaches that can be used specifically to counter online vaccine misinformation.

General approach to tackling online vaccine misinformation

Evidence suggests that the composition of messages intended to correct vaccine misinformation should follow the same principles as general vaccination communication techniques that have previously been described, including in ECDC publications [59–61]. These include strategies such as positive message framing, the use of interactive tools, and storytelling. A study by Kim et al [62] found that corrections using humour can be effective in reducing misconceptions about vaccines but should be used with caution as they can decrease the credibility not just of the source of the misinformation but also of the correct information.

Another important aspect of tackling misinformation concerns how to disseminate corrective information in a way that reaches the intended audience. Given that many people are exposed to vaccine-related information in informal settings, such as on social media platforms, some experts believe that national health authorities must be present in those spaces [63–65]. The official pages of national health authorities on social media can serve as more user-friendly sources of information than official websites. Interaction with audiences through social media also allows for instant feedback from the audience. Interviewed country representatives report using platforms such as Twitter and Facebook for sharing information with the public, as well as for responding to questions and claims containing misinformation. One study by Zhao also finds that having national authorities present on multiple social media platforms may be beneficial as it allows the sharing of messages across those platforms and thus amplify the reach and thereby, it is hoped, the effectiveness of the messages [55].

Experts recommend using tailored approaches to countering vaccine misinformation. Studies find that tailored messages are more effective in correcting misinformation claims, even in groups that are considered more prone to believing misinformation [24]. The groups that should be targeted may vary greatly between countries. The majority of interventions in the analysed studies targeted individuals in the age group of 19 to 45 years old i.e. the category of (potential) parents, although it is important to note that the findings from these studies would need to be carefully considered in the context of a population-wide vaccination strategy, such as that for COVID-19. As discussed previously, some studies have found that women and ethnic minorities may be more susceptible to misinformation [1,29]. Targeting is particularly feasible in countries where there are monitoring systems, as here the profiles of people exposed to and sharing misinformation are clearer and messages can be targeted at them directly.

Corrective information in response to misinformation claims must come from trusted sources. One study found that 'source trustworthiness' is more important than source expertise in reducing misconceptions, meaning that people are more easily persuaded by a source that they trust regardless of whether the source is an expert [5]. This finding was also supported by our interviewees.

Techniques for countering online vaccine misinformation

The above section discussed some of the general approaches to tackling vaccine misinformation. All these can be applied to developing messages that can affect public perceptions of misinformation. When it comes to applying the above-discussed approaches, two main techniques have been discussed in the literature, as well as by interviewees. Those are **debunking** and **inoculation**. Each of these is presented in detail below.

Debunking

Debunking refers to a technique of correcting erroneous claims by providing counter-arguments to messages containing misinformation. Debunking is challenging due to the strong convincing effects of misinformation. Simply informing people that a piece of information is false is rarely enough. It is important to use persuasive techniques to refute the misinformation claims. Effective debunking requires a tailored approach that incorporates different influence mechanisms [24,62].

Although the literature highlights that debunking is the primary technique employed by health communication specialists, studies are inconsistent in the observed effectiveness of correcting misinformation. While some studies have found debunking to be effective in changing vaccine perceptions, others have shown little effectiveness, or even a backfire effect, i.e. that corrective interventions can increase vaccine hesitancy [3–5,66]. Some attribute this effect to the fact that even a corrective message still repeats the misinformation, thus giving it undue exposure. Moreover, debunking messages may reinforce the rhetoric used by those spreading the misinformation piece, i.e., by debunking misinformation, the suggestion can be raised that the rationale has merit even though the point is incorrect.

Some studies also stress that correcting existing misinformation beliefs is extremely challenging given that individuals' prior views are a strong determinant of whether corrective interventions will be effective [4,5,55,62]. This is in line with other studies that highlight the importance of personal belief systems as a predictor of susceptibility to vaccine misinformation. At the same time, one study shows that a lack of corrective response from national health authorities may amplify the effects of misinformation, and that debunking as an intervention is more effective than no intervention at all [53]. The backfire effect of corrective messages reportedly only

occurs rarely: generally, debunking messages are effective in demonstrating the fallacy of the original piece of misinformation.

Given the advantages and disadvantages of debunking, experts support the idea of 'careful debunking'. *The Debunking Handbook*, developed by the leading scientists in the field of countering misinformation, provides useful guidelines for the use of debunking, including when to correct misinformation pieces, who should correct misinformation, advice on the structure of corrective messages, and general recommendations on the use of the technique [67]. The core technique of the debunking approach involves presenting the misleading claim and explaining the nature of fallacious logic behind the statement.

Interviewees from national health authorities and other organisations report the frequent use of debunking through the issuing of statements, social media posts, press releases, and other communication mechanisms. However, they provide little to no insight into the effectiveness of their actions, as this is rarely monitored.

Inoculation

While debunking refers to post-exposure correction of misinformation, inoculation is a pre-emptive action, warning people in advance of how misinformation is used and giving them the ability to 'resist' such information should they be exposed to it in the future [68]. It does this by explaining the misleading argumentation and techniques used by those spreading misinformation [67]. The inoculation theory offers a structure for pre-emptive messages to offset misinformation, similar to the effects of vaccines in the body (hence the term 'inoculation'): exposure to an attenuated form of the virus helps build resilience to the wild type virus. Similarly, exposure to 'attenuated' forms of misinformation along with an explanation of their fallacies helps the reader become less vulnerable to misinformation they may encounter in the real world. An interesting example of this is the '**Go Viral!**' game produced by the University of Cambridge, designed to protect players against COVID-19 misinformation by showing strategies used to spread false and misleading information. Similarly, a satirical card game called '**Antivaxers**' has been developed in Poland by a physician and team of programmers with the goal of 'immunising' players against anti-vaccine claims.

The notion of using such 'inoculation' to counter vaccine misinformation has only emerged recently. However, this idea has been studied in somewhat more detail in the areas of science denial and climate misinformation [44,69,70]. Some studies on climate science communication find that by explaining how false media coverage can mislead people, the typical negative impact of false media coverage vanishes [44,69]. Moreover, inoculation seems to help train the skills necessary for a critical assessment of information while also increasing resistance to other types of misinformation besides the ones mentioned in the inoculation message [39,44]. Another positive effect of inoculation is that it can influence people to talk about issues they become exposed to: people are more likely to share their understanding of flawed misinformation narratives when they can identify the flawed arguments [44].

Figure 2 presents an example of the inoculation approach used in the area of climate science. The extract is taken from an experiment described in the study by Cook et al (2017) on the effects of inoculation in neutralising misinformation [69]. A similar approach can be taken to design inoculation messages for vaccine misinformation.

Figure 2. Example of inoculation approach applied in climate science

The following text was excerpted from the Global Warming Petition Project website, run by the Oregon Institute for Science & Medicine.

Step 1. Presenting a misinformation piece

Petition

We urge the United States government to reject the global warming agreement that was written in Kyoto, Japan in December, 1997, and any other similar proposals. The proposed limits on greenhouse gases would harm the environment, hinder the advance of science and technology, and damage the health and welfare of mankind.

There is no convincing scientific evidence that human release of carbon dioxide, methane, or other greenhouse gases is causing or will, in the foreseeable future, cause catastrophic heating of the Earth's atmosphere and disruption of the Earth's climate. Moreover, there is substantial scientific evidence that increases in atmospheric carbon dioxide produce many beneficial effects upon the natural plant and animal environments of the Earth.

Please sign here

☒ Please send more petition cards for me to distribute.

My academic degree is B.S. ☐ M.S. ☐ Ph.D. ☒ in the field of PHYSICS

Step 2: Putting the presented piece into the larger context, educating the reader on tricks used by the misinformation spreaders

Fossil fuel and political groups try to cast doubt on climate science, in order to delay regulation of the fossil fuel industry. They do this by manufacturing the appearance of an ongoing scientific debate.

The 'fake debate' strategy was pioneered by the tobacco industry in the 1970s. They used doctors and scientists to reassure the public that smoking didn't cause health problems. These spokespeople were either non-experts or among the small minority of scientists who dissented from the scientific consensus that smoking is bad for you. However, in the public's eye, this conveyed the appearance of ongoing scientific debate.

The 'Tobacco Strategy' is being used again, but this time to cast doubt on climate science. Less than 3% of climate scientists disagree with the consensus position that humans are causing global warming. However, when the media present the views of a dissenting scientist alongside a mainstream scientist, the public comes away with the mistaken impression of a 50:50 debate. Ironically, the journalistic standard of giving both sides equal weight has ended up distorting the state of climate science.

Source: Cook et al (2017) [69]

Some experts interviewed believe that inoculation is the most effective approach to halt the spread of misinformation, as it can make people resilient to subsequent manipulation attempts. Interviewees and study authors believe that the process of inoculation goes hand in hand with improving digital and health literacy and should be carried out early in one's life through educational approaches and with the involvement of different actors, such as teachers, health professionals, policymakers, and scientists.

5. Discussion

5.1 The role of online and social media in vaccine misinformation

Misinformation about vaccines and vaccination policies can cause significant harm to a country's vaccination efforts by undermining public trust in vaccines and reducing vaccine acceptance. Although online vaccine misinformation is not new, interviewed stakeholders observed that the rise of social media has greatly amplified the phenomenon. This study identified online vaccine misinformation in all six case study countries. As this study only analysed information on a relatively small number of public platforms, it likely underestimates the true extent of misinformation to which people are exposed in the selected countries. An analysis of 1.8 million vaccine-related posts on Twitter between 2014 and 2017, using machine learning, identified as many as 22% of all posts as antivaccine [71]. Importantly, exposure to misinformation is not random: the algorithms used by platforms such as Facebook, Twitter, and YouTube create 'filter bubbles' or 'echo chambers' in which those who have shown interest in specific pieces of (mis)information are then suggested further similar content [72]. Exposure to misinformation can thus be quickly amplified for those who have previously engaged with it.

Social media platforms differ in the speed with which content is generated, their reach, formats and sharing options, and consequently in their impact. This study identified posts with very high engagement on YouTube and, to a lesser extent, also on Twitter, but methodological limitations preclude a direct comparison across platforms. The literature offers more insights into their relative importance. Facebook and YouTube are currently the platforms with the highest numbers of active users [73]. However, a 2019 study suggested that between 2015 and 2018 the misinformation problem (not specific to vaccination) was decreasing on Facebook following changes to the site's algorithms and policies, while it continued to rise on Twitter [74]. Nonetheless, a greater presence of misinformation need not automatically translate into greater reach or impact. For instance, a 2020 study on the spread of 'Fake News' during the 2019 European elections found that Twitter conversations were largely confined within networks of like-minded individuals, and also rarely crossed national borders [75]. Further, evidence suggests that it is not only the platform but also the **format of the content** that plays a role in the likelihood and extent of it spreading online. Marketing studies suggest that posts containing visual content – such as photos, videos and GIFs – have significantly higher engagement on social media than those that are purely text-based [76]. Whereas much of the visual content encountered in this study was of low production quality, there are notable exceptions, with videos that appeared to have been professionally edited and that relied on health professionals or medical jargon to bolster their credibility.

In addition to the specific platforms or formats, the reach and influence of those involved in spreading information also matters. Social media have given rise to so-called '**influencers**': people with a large online following and the power to inspire particular behaviours in others. If misinformation is posted on the accounts of such influencers, this increases the likelihood that it will spread and thereby do harm. Public health authorities need to be aware of such influencers and their messaging about vaccines.

5.2 The role of public authorities in countering online vaccine misinformation

Among the national public health authorities interviewed for this study, there is a clear awareness of the threats posed by online vaccine misinformation. However, the extent to which they **prioritise countering misinformation** is not always clearly associated with the actual level of online vaccine misinformation circulating in the country. Rather, it appears linked with concerns about low or declining vaccination rates and whether resources (human, financial, and technical) are available to implement such efforts. Authorities from the countries involved also vary in the degree to which they are familiar with strategies for monitoring online vaccine misinformation and in their capacity to address it. Few have adopted a continuous strategic approach in this respect. Most of the stakeholders interviewed for this study see a real and urgent **need for national public health authorities to be better trained in identifying misinformation**, for instance through monitoring of social media, **and in techniques for countering it effectively**.

This study has provided insights into various aspects of online vaccine misinformation, such as how it spreads, who it targets, and what it looks like, and into strategies and tools for countering it. As such, the results offer a useful resource to public health authorities for the development of strategies for tackling online vaccine misinformation. We identify the following four key areas on which effective strategies for countering online vaccine misinformation should be built:

- Monitoring of misinformation on social media;
- Debunking of misinformation;

- Pre-emptive interventions; and
- Evaluation of the effectiveness of interventions.

These key areas should be included in any future training programme on countering online vaccine misinformation for public health professionals in EU Member States. They are each discussed in more detail in the following sections.

5.2.1 Monitoring misinformation on social media

To better understand the nature of online vaccine misinformation, the specific narratives that are being circulated and the audiences that are being targeted, it is important for public health authorities to **routinely monitor the main social media channels** [21,27,30,31,33,52,54]. Without the knowledge that can be derived from social media monitoring, public health authorities cannot properly identify which claims should be debunked nor how, when, or where to do this. The speed with which online (vaccine) misinformation is spread, as well as its diverse nature, means that such monitoring can no longer be done manually but requires sophisticated tools and techniques, including big data analytics.

The successful application of social media monitoring techniques requires know-how. Evidence from the six case study countries suggests that this expertise is not yet widely present in some EU public health authorities and that **investment is needed to build this capacity, both in terms of skills and technological infrastructure**. The specific needs for this type of skills development differ between the case study countries. Thus far, only the Netherlands conducts continuous routine social media monitoring by a dedicated unit and using a specialised monitoring tool. In some other case study countries, monitoring is done informally and without such tools. In some of the participating case study countries, it was indicated that further developing the capacity to conduct routine social media monitoring would necessitate human resources and budget beyond what is currently available. Making these resources available would require **greater (political) prioritisation** of the issue.

5.2.2 Pre-emptive interventions

Even with effective social media monitoring and identification of sources, the creation and transmission of online vaccine misinformation itself cannot be completely stopped. Public authorities should therefore aim to minimise the risks that result from exposure to vaccine misinformation. One way of doing this is by **pre-emptive interventions** to reduce the susceptibility of people to misinformation. The rationale for investing in pre-emptive interventions is that it is generally easier to promote 'fresh' beliefs than change already held ones: people are inclined to favour information that fits within their existing belief systems even if that information is incorrect [1,3,21,22].

Several studies have shown that resilience to vaccine misinformation significantly depends on a person's level of **digital, health, and science literacy** [4,5,33,38,39]. The spread of misinformation halts when a person can correctly identify misinformation as such by applying critical thinking skills to assess the credibility of a source and the content of the message. Techniques that can be used to improve digital literacy and boost resilience to misinformation include misconception-based learning and '**inoculation**' [43,69,70]. Such techniques aim to give people a better understanding of common strategies used in spreading misinformation by demonstrating these strategies in action, thereby increasing their capacity to recognise and resist misinformation when exposed to it. However, interviewed representatives of public health authorities indicate that these techniques are not currently widely used.

Although the evidence (as presented above in Section 4.4) suggests that pre-emptive interventions can be very powerful in countering online misinformation in the long term, they are complex and require **multi-stakeholder engagement** and **multidisciplinary approaches**. For instance, to promote critical thinking skills and increase health literacy, public health authorities could work with educators to develop appropriate school-based curricula based on up-to-date scientific information. Approaches around inoculation could be designed in collaboration with experts in communication sciences, (digital) marketing and, for gamification-based interventions, software developers and web designers.

5.2.3 Debunking

Whereas pre-emptive interventions can be an important component of strategies to tackle online vaccine misinformation, their effects may not be immediately apparent. National health authorities should therefore consider focusing simultaneously on more reactive measures, such as **correcting misinformation through debunking**. Debunking refers to 'post-exposure' correction of misinformation by providing **evidence-based counterarguments**. While debunking may be less effective than pre-emptive interventions, it serves a purpose when these interventions were not carried out (on time) or were not successful.

The evidence derived from the literature, as well as the experiences of interviewed stakeholders, all points to the conclusion that **debunking is challenging and needs to be done with great caution** [4,5,55,62]. The challenge lies primarily in the need to replace existing false beliefs with new correct ones. Simply informing people that a piece of information is false is often not enough and may in fact be counterproductive by amplifying the false information or increasing distrust [3–5,66]. To maximise the effectiveness of debunking, it is therefore important to use persuasive techniques when framing messages. Those can derive from general vaccine communication guidelines, some of which have been described in this study, such as the use of experts or humour.

The use of tailored messaging is considered another important success factor, which may be particularly useful in the online setting [1,24,29]. Public health authorities that use social media data analytics based on monitoring can better understand the social media landscape and can thereby design more effective debunking messages that target specific groups based on user characteristics.

Most countries included in this study apply some form of debunking, although to a different extent and through the use of different techniques. Estonia, Spain, France, and the Netherlands report debunking misinformation claims openly, either routinely or in special cases, while in Romania debunking is performed in a less systematic manner by experts answering questions from the public. Debunking does not appear to be widely used by the German national public health authorities consulted for this study. Note that the application of debunking can vary between regions and other national institutions, so these findings may not be representative of the entire country.

5.2.4 Evaluation

Although the literature included in this study offers some examples of strategies for countering vaccine misinformation that have been evaluated in controlled settings, the evidence base offers little insight into their effectiveness in other settings [77,78]. Moreover, none of the national health authorities represented in this study routinely evaluates the effectiveness of their efforts in countering vaccine misinformation. Understanding the effects of these efforts is challenging, particularly in a fast-paced environment where new platforms and narratives continue to appear and where those who spread misinformation remain largely anonymous. However, **effectiveness data are needed to develop a more robust evidence base and improve practices** to counter online vaccine misinformation. National public health authorities should therefore assess whether there is a need to increase their efforts to monitor and evaluate (M&E) the effect of their activities in this space.

Through use of appropriate M&E techniques, authorities can adopt a learning-based approach, which allows strategies to be adjusted based on what works and what does not [79,80]. Although it may not be feasible to routinely assess the effectiveness of specific actions, there may be more scope for **empirical studies in the context of 'high visibility' events**, such as with the introduction of new vaccines or outbreaks of vaccine-preventable diseases. By monitoring trends in the volume and type of misinformation shared around such events and combining this with data about specific countering strategies, authorities may be able to determine whether these strategies have had the intended effect of reducing the spread of misinformation.

While the scientific evidence base for various techniques to counter online vaccine misinformation is growing, **knowledge sharing between countries** is also important. This study suggests that approaches to countering vaccine misinformation vary greatly between countries, and that institutions have little to no awareness of the approaches used by their counterparts in other countries. There appears to be significant room, therefore, for expanding the sharing of information and cross-country learning.

5.3 Limitations of this study

There are several limitations to this study. Firstly, the context in which the study took place was extremely fluid, as the COVID-19 pandemic further unfolded across Europe and as vaccines were developed. During the study period, the number of publications and media postings regarding COVID-19 and COVID-19 vaccines grew enormously. As a result, misinformation about other diseases and vaccines in the scope of this study may have been crowded out, and the findings presented here are not necessarily representative of the entire vaccine misinformation landscape.

In each of the case study countries, only a limited number of interviews were conducted with representatives of national public health authorities. As these authorities may not be the sole entity involved in countering online misinformation in the respective countries, the data presented here may not cover the full spectrum of activities undertaken in these countries.

Several limitations apply also to the social media analysis. First, the Awario tool that was used could only identify content from open sources, and could not access content shared in private groups or via encrypted platforms. This is likely to have resulted in an undercount of the amount of misinformation available online and possibly a biased view of the misinformation that was analysed. Second, the tool did not allow for geo-tagging of

information. Instead, assignment to specific case study countries was done on the basis of language. As a result, posts in languages also spoken in other parts of the world could have been incorrectly assigned to the case study country, resulting in overcounting of the absolute number of postings. The subsequent analysis could also have been biased, as the proportion of misinformation may be substantially different in other countries. Conversely, the methodology did not account for posts in minority languages spoken in the case study countries.

A further limitation pertains to the classification of misinformation. All classification was done manually, based on the criteria presented in section 2.3. As such, the process was inherently subjected to the perceptions and understandings of the researchers. Moreover, pieces of information were considered at face value without assessment of their underlying intent. Statements could thus be labelled as misinformation even if they were intended to be satirical. This may have overestimated the share of misinformation within the analysed sources.

Due to these limitations, some care should be taken in interpreting the data presented here and in extrapolating the findings to other settings. Nonetheless, these findings do approximate the extent to which the countries included in the study are affected by online vaccine misinformation, and they illustrate the efforts that national public health authorities have taken in response.

6. Conclusions

Vaccine misinformation poses risks to national vaccination efforts as it can lead to increased vaccine hesitancy which, in turn, reduces vaccination uptake. Effectively countering vaccine misinformation should focus on two key elements: (i) the identification and continuous monitoring of the online misinformation landscape, along with (ii) the development of timely, evidence-based responses to misinformation claims. This work should be supported by longer term efforts aimed at enhancing digital literacy and critical thinking in the population.

The national public health authorities that took part in this study understand the dangers associated with vaccine misinformation and the need to counter it effectively. However, existing practices aimed at countering it vary across the EU. National public health authorities in the selected countries identified a strong need for skills training on how to counter vaccine misinformation. When organising such training, it is important to ensure sufficient human, technical, and financial resources.

Susceptibility to vaccine misinformation is associated with sub-optimal digital, health and science literacy. While national health authorities play an important role in the countering of vaccine misinformation, addressing the root causes for the spread of misinformation is unlikely to be attained without the development of new educational approaches aimed at improving the public's critical thinking and appraisal skills. As these skills are not specific to vaccine information, or even to health information in general, the development of suitable curricula should involve a wide variety of actors, including social scientists, educators, and communications experts. In parallel, health professionals will continue to be important as trusted sources of information promoting vaccination.

Through this study, the following key areas have been identified for consideration by national health authorities in their efforts to counter online vaccine misinformation:

- Monitor the local (social) media landscape to understand the information needs and concerns of the public, and dedicate special resources (human, technical, financial) to the implementation of systems to monitor and counter online vaccine misinformation.
- Occupy the social media space and engage in proactive vaccine communication.
- Use interdisciplinary expertise – including public health experts, big data analysts, digital health experts, behavioural psychologists and communication specialists – to amplify the efforts in countering online vaccine misinformation.
- Apply a (more) strategic approach for vaccine communications in general, and for responding to online vaccine misinformation in particular, with aligned messaging between involved parties.
- Learn and apply effective inoculation and debunking communication techniques to constructively engage with people who have sincere questions, using an empathetic approach.
- Develop training opportunities for health professionals and health communication experts to become more versed in effective techniques and tools for countering online vaccine misinformation.
- Develop communications and social media training for public health professionals that will equip them to act effectively in a constantly changing and complex media environment.
- Search for partnerships such as with traditional media, online platforms and stakeholders in education and training, to increase digital and health literacy of the public in the mid- and longterm.

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Annex 1. Acknowledgement of interviewees

Name	Organisation
Kathryn Owens	Directorate-General for Health and Food Safety, European Commission
Jeanine Pommier	ECDC
Alexandra Cucu	National Institute of Public Health, Romania
Sandrine Randriamampianina	Santé Publique, France
Natalie Grams-Nobmann	Robert Koch Institute, Germany
Mirjam Jenny	Robert Koch Institute, Germany
Stephan Lewandowsky	University of Bristol, United Kingdom
Jacques de Haller	The Standing Committee of European Doctors (CPME)
Irina Filippova	Estonian Health Board
Eike Kingsepp	Estonian Health Board
Esther Rikkengaa	National Institute for Public Health and Environment (RIVM), the Netherlands
Ingrid van den Broek	Ministry of Health, Welfare, and Sport, the Netherlands
Marta Soler Soneira	Ministry of Health, Spain
Laura Sánchez-Cambronero Cejudo	Ministry of Health, Spain
Inmaculada Puig Baviera	Ministry of Health, Spain
Angel Suarez Iglesias	Ministry of Health, Spain
Roman Adamczyk	EU DisinfoLab
Representative	EUvsDisinfo/European External Action Service
Tim Nguyen	The WHO Regional Office for Europe
Sandra Cavallo	Directorate-General for Communication, European Commission
Matteo Salvai	Directorate-General for Communication, European Commission

Annex 2. Interview questionnaire

0. **Introduction**: We will start by summarizing the present information leaflet and provide an introduction on who we are, the project, definition of misinformation, and disease selection.
1. Do you **monitor online misinformation** about vaccines and vaccinations in your country/in Europe?
2. Have you identified **who** is spreading this misinformation (who are they and what is motivating them?), through **which channels** and **how**? Are those influencers **targeting** specific groups of populations?
3. Please tell us about your experience with **countering online misinformation**. Which **strategy** did you/do you apply? What did this strategy **aim** for?
4. How did you **implement** this strategy? Which means did you/do you use? What support did/do you need for this task? What **resources** do you have available for this? Is this an issue that is prioritised in your country?
5. Did/do you **measure** that your practice was/is **effective or ineffective**? How did/do you this? Which indicators did/do you use?
6. Which strategies do you consider **feasible** within certain limits such as available time, budget and responsiveness of public institutions or associations?
7. Which **resource-light interventions** would you recommend to colleagues in other EU Member States?
8. Do you see a **need** to be better **trained** or better equipped to counter online vaccine misinformation and if so, what especially would you look for?
9. Are you aware of **existing trainings** or courses which address the issue of online misinformation (possibly also beyond the topic of vaccines/vaccinations)? If so, can you share this information with us?
10. Which **other organisations** in your country/in Europe who work on countering misinformation (on vaccinations) would you recommend us to contact in order to learn more about what works and what doesn't work?