

JITSUVAX: Jiu-Jitsu with Misinformation in the Age of Covid

Taxonomy of fallacious arguments against vaccination

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Purpose of this document

This document contains a report on the psychological taxonomy of anti-vaccination arguments, produced for the JITSUVAX project as part of Work Package 2.2 'Developing Jiu Jitsu interventions'. This analysis of anti-vaccination arguments provides an underlying structure for the abundance of misinformation found online and will feed directly in to the develop of interventions to tackle this misinformation in later stages of JITSUVAX.

Summary

The proliferation of anti-vaccination arguments, especially on the Internet and social media, is a threat to the success of many immunisation programmes, including for COVID-19. Effective rebuttal of such contrarian arguments requires an approach that goes beyond addressing flaws in the arguments, by also considering the attitudinal roots – i.e, the underlying psychological attributes driving a person's belief – of opposition to vaccines. Through a systematic literature review and thematic analysis of anti-vaccination arguments, we developed a hierarchical taxonomy of anti-vaccination arguments that not only identifies common and recurring themes, but, crucially, relates the arguments to eleven attitudinal roots that explain why an individual might express opposition to vaccination. We validated our taxonomy on a new dataset of COVID-19 anti-vaccine misinformation, using a combination of human coding and topic modelling through Latent Dirichlet Allocation (LDA). The human coders identified attitudinal roots for a sample of more than 600 debunked claims about COVID-19 vaccinations, and the LDA model predicted these assigned roots above chance level. Overall, the taxonomy serves as a starting point to link expressed opposition of vaccines to their attitudinal roots. This enables us in future work to develop targeted rebuttals that address both these components of anti-vaccination argumentation.

Project overview

Vaccine hesitancy – the delay or refusal of vaccination without medical indication – has been cited as a serious threat to global health by the World Health Organization (WHO) which attributed it to misinformation on the internet. The WHO has also identified Health Care Professionals (HCPs) as the most trusted influencers of vaccination decisions.

JITSUVAX will leverage those insights to turn toxic misinformation into a potential asset based on two premises:

- 1. The best way to acquire knowledge and to combat misperceptions is by employing misinformation itself, either in weakened doses as a cognitive "vaccine", or through thorough analysis of misinformation during "refutational learning".
- 2. HCPs form the critical link between vaccination policies and vaccine uptake.

The principal objective of JITSUVAX is to leverage misinformation about vaccinations into an opportunity by training HCPs through inoculation and refutational learning, thereby neutralizing misinformation among HCPs and enabling them to communicate more effectively with patients. We will disseminate and leverage our new knowledge for global impact through the team's contacts and previous collaborations with WHO and UNICEF.

Rationale for this report

In order to tackle the misinformation and anti-vaccination content that is widely distributed on social media networks and other online platforms it is important to first identify this content. Comparing the content circulating in the various countries involved in JITSUVAX contributes to understanding how contrarian argument develops as it circulates, while categorisation brings an efficient underlying structure to the undifferentiated abundance of online misinformation.

The taxonomy reported here will inform numerous other components of the JITSUVAX project. We review those other aspects of the project briefly.

Work Package 1

As part of Work Package 1 (WP1), we will ask healthcare professionals (HCPs) to rate how persuasive they find different anti-vaccination arguments. The taxonomy provides us with thematic categories that we used to extract prototypical arguments (see column in Table 1) for this task. A selection of those prototypical arguments will be presented to HCPs for ratings of persuasiveness and other comments.

These data will be gathered at all nodes and in all languages involved in JITSUVAX (viz. English, German, Swedish, Finnish, French, and Portuguese). By gathering data on argument ratings across the different nodes, we will assess the relevance of each theme to vaccine opposition in different languages and countries.

The taxonomy will further inform the qualitative interviews with HCPs in WP1.3, whereby a topic guide including the main contrarian arguments from each theme will be developed to probe HCPs' vaccine hesitancy and confidence.

Work Packages 2 and 3

The taxonomy will also provide the foundation from which to develop targeted rebuttals to antivaccination arguments, which are essential to WP2.2 and WP2.3. In WP2.2, we plan to develop an interactive application (e.g. a website or browser plug-in) that can be used by HCPs during their interaction with patients. Critically, this application should provide HCPs with effective rebuttals of contrarian arguments that they may encounter. The taxonomy facilitates this in two ways: First, by identifying common themes to be rebutted. Second, because of the link to the deeper attitudinal roots associated with each theme, the taxonomy can be leveraged to help HCPs gain a better understanding of why a patient may be refusing a vaccine, based on their expressed opposition.

In WP2.3, the objective is to develop and test refutational techniques for HCPs, based on refutation of common anti-vaccination arguments. The taxonomy thus lays the groundwork for identifying the best arguments to include in this WP, as well as developing more effective refutational texts that can be aligned with the attitudinal roots of the argument.

Ultimately, the rebuttal tools and refutational techniques that are supported by the taxonomy will be field tested in WP3, where HCPs will be trained to use refute anti-vaccination arguments in their interactions with colleagues and patients.

A Report on the Psychological Taxonomy of Anti-Vaccination Arguments

General Introduction

Vaccinations are arguably one of the most impactful medical inventions, having contributed to the eradication of many infectious diseases and preventing millions of deaths from these diseases each year (Greenwood, 2014). Despite the success of vaccines, there remains a worrying number of people who reject vaccination, to the extent that the World Health Organization (WHO) in 2019 declared vaccine hesitancy to be one of the top ten global health threats (World Health Organization, 2019). Vaccine hesitancy – a concept that encompasses a spectrum of attitudes, from refusal of all vaccines to accepting vaccination despite uncertainties about doing so (MacDonald, 2015) – poses a barrier to achieving vaccination in sufficient levels to protect all communities (Ball & Maxmen, 2020; Karlsson et al., 2021). The seriousness of the problem is highlighted in the COVID-19 pandemic, as a large-scale global vaccination effort is widely acknowledged to be critical to ending the pandemic (World Health Organization, 2021).

The drivers of low vaccine uptake are varied and range from the pragmatic, such as lack of access or inability to take time off work, to psychological variables that drive people's hesitancy to get vaccinated. Disentangling these factors is important because they require different countermeasures. For example, pragmatic factors such as the lack of vaccination clinics nearby require logistic solutions. By contrast, psychological and attitudinal factors require a behavioural or persuasive response, which in turn requires a nuanced understanding of the numerous psychological factors—from complacency to a lower sense of community responsibility to distorted risk perceptions or fear of side effects (Betsch et al., 2018). It is only through an understanding of those various psychological factors that solutions can be developed that are targeted at the specific reason why an individual does not get vaccinated. In this report, we are primarily concerned about contrarian arguments that are employed in conversations or on social media to justify hesitant attitudes toward vaccinations or to discourage others from being vaccinated.

There has been a worrying proliferation of deliberate misinformation on the Internet, especially on social media (Center for Countering Digital Hate, 2021; Peretti-Watel et al., 2019; Smith & Graham, 2019).

Correcting anti-vaccination arguments can be a challenge for a number of reasons. First, misinformation is notoriously difficult to correct (Lewandowsky, Ecker, Seifert, Schwarz, & Cook, 2012). One of the insights from research on misinformation is that people may accept a correction of a flawed or false argument (Swire, Berinsky, Lewandowsky, & Ecker, 2017; Swire-Thompson, Ecker, Lewandowsky, & Berinsky, 2020), but then may nonetheless continue to rely on the incorrect argument to inform their decision or preferences (Ecker, Lewandowsky, & Apai, 2011; Ecker, Lewandowsky, Swire, & Chang, 2011; Swire et al., 2017; Swire-Thompson et al., 2020). Second, there are occasions when people cling even harder to their beliefs when they are debunked, especially if correcting the misinformation in their argument disrupts their worldview (Lewandowsky, Stritzke, Oberauer, & Morales, 2005; Nyhan & Reifler, 2015). Efforts to directly debunk misinformed antivaccination arguments can therefore, ironically, strengthen vaccine hesitancy (Pluviano, Watt, & Della Sala, 2017). It follows that effective rebuttal of anti-vaccination arguments requires a targeted approach that takes into account an individual's likely reason for believing those arguments.

Refutational approaches that use the misinformation itself in a correction (van der Linden, Leiserowitz, Rosenthal, & Maibach, 2017, e.g. "inoculation" with a weakened form of the argument) or analysis of its misconceptions (Kendeou, Butterfuss, Kim, & Van Boekel, 2018; Kowalski & Taylor, 2009, e.g. "refutational learning") have been demonstrably successful in countering anti-vaccination misinformation. Hornsey and Fielding (2017) proposed a variant of refutation that they likened to "jiu jitsu"; that is, the martial art that uses the opponents' force against them. The idea of the original jiu jitsu approach was to align persuasive efforts with attitudinal "roots" underlying the surface expression of contrarian attitudes (e.g. a commitment to unregulated free markets can be a root that is driving opposition to vaccines for fear of government interference). Here we extend the jiu jitsu approach by turning the toxic power of misinformation into a potential asset, either through the inoculation with a cognitive "vaccine" or through thorough analysis of misinformation so it can be used to create rebuttals that are aligned with people's attitude roots. To pursue this approach, one needs to analyse misleading anti-vaccination rhetoric and identify, first, the main organizing "themes" (sometimes also referred to as "tropes") that are inherent in the messages, and second the psychological root constructs these themes tap into.

While past research has conducted several substantial thematic analyses of anti-vaccination content, an analysis of how these themes tap into different psychological roots related to vaccine hesitancy is lacking to date. Understanding how anti-vaccination themes relate to specific psychological constructs is important for two reasons. First, countering a message alone may not be effective if it does not address the hesitant individual's motivations to oppose vaccination (Hornsey & Fielding, 2017). Second, identifying the psychological construct that drives hesitancy could help to predict susceptibility to certain themes, allowing more targeted misinformation inoculation to be developed. When examining anti-vaccination messages online, certain themes frequently recur. A recent systematic review of anti-vaccination messages on social media (Wawrzuta, Jaworski, Gotlib, & Panczyk, 2021) predicted, and found, two identifiable themes discussed in the past literature: Vaccines as unhealthy or ineffective, and vaccines as part of a conspiracy. Although both themes are important for public health communicators to address, they are clearly non-exhaustive. Other studies have found further anti-vaccination themes related to religious concerns, worldview justification, and pseudoscientific arguments, among others (Hughes et al., 2021, e.g.). Although efforts have been made to develop a code for anti-vaccination themes, most recently in the context of COVID-19 vaccinations (Hughes et al., 2021), a more comprehensive taxonomy is still needed to assess the antivaccine sentiment contained in a message. This report thus seeks to organise and unify the disparate contrarian arguments against vaccines that proliferate online and relate it to a set of psychological constructs that help identify the root of an individual's anti-vaccine attitude. Such a taxonomy is particularly useful for determining a psychological profile for each type of argument, locate vulnerable populations with low vaccination rate (or are at risk of reducing their vaccination rate), and develop effective interventions aimed at increasing vaccine uptake – for example, when an argument against vaccination is characterized as a conspiracy theory, the health care professional can use evidencebased strategies developed to deal with the conspiracy ideation (Lewandowsky & Cook, 2020).

The remainder of this report is structured as follows. First, we briefly describe some of the existing literature on the reasons for vaccine refusal that motivated the need for our taxonomy and provided the theoretical and empirical foundations for the initial conceptualisation of the taxonomy. Next, we describe the methodology by which we developed and refined our taxonomy. We then present the hierarchical structure and components of the taxonomy, including detailed descriptions of the "attitude roots" identified in the scientific literature. Finally, we report two empirical analyses that we conducted to validate and refine the taxonomy in an iterative process: (1) a pre-registered systematic

literature review of scholarly work on anti-vaccination arguments and (2) mapping our taxonomy onto COVID-19 anti-vaccine misinformation mined from fact-checking sites collected through the covid19misinfo.org portal (Gruzd & Mai, 2020). We used the corpus of fact-checked misinformation as a proxy for a direct quantitative analysis of social-media content. We show through computational text modelling that our taxonomy derived from the scientific literature has out-of-sample skill in identifying the psychological roots underlying misinformation circulating on the Internet. We conclude the report by explaining how this taxonomy can be of practical use as a tool for assessing the psychological profile for different types of contrarian arguments, rebutting anti-vaccination arguments, and identifying populations vulnerable to anti-vaccination messaging, with a focus on healthcare settings (e.g. use by health care practitioners) in particular.

Anti-vaccination arguments: A brief survey of the previous literature

Numerous studies have catalogued the content of websites and social media related to anti-vaccine arguments and misinformation (e.g. Hoffman et al., 2019; Hughes et al., 2021), typically grouping them into thematic categories. There is substantial overlap in the categories identified, attesting to the identifiability and stability of anti-vaccination argumentation. There is, however, considerable variation in terminology, with researchers variously calling these categories "themes", "tropes", or "narratives". Some also use the terms "strategies" or "tactics" to distinguish different modes of persuasion used in the messages. For example, Kata (2012) identifies 14 "tropes" in anti-vaccination messages on the Internet and 4 "tactics" used by anti-vaccination movements to spread these messages. In Kata's terminology, tropes refer to over-arching narratives, such as the claim that "vaccines are unnatural", whereas tactics refer to rhetorical tools such as attacks on critics.

While not all studies differentiate between the narrative content of a message and its method of persuasion, the distinction is identifiable in most cases. For example, Hoffman et al. (2019) coded for themes that included "activism" (which could fit different narratives but is generally related to a method used to promote the anti-vaccination movement) as well as "homeopathic remedies" (which clearly relates to an overarching narrative about complementary and alternative medicine). Likewise, Zimmerman et al. (2005) identifies the strategies of "promotion of vaccine criticism" and "emotive appeals" alongside the narrative themes of "alternative medicine" and "vaccine safety" as characteristics of anti-vaccination websites (although within those themes, the authors also identify sub-characteristics that relate to the rhetorical strategy used, such as using personal stories in the message).

The existing literature illustrates the themes that recur in anti-vaccination messages in online spaces, all of which are primarily based on misleading or false information (e.g. Center for Countering Digital Hate, 2021; Hughes et al., 2021). Consolidating these previously analysed themes serve as a strong starting point for a unified classification of anti-vaccination arguments. To our knowledge, there has been only one systematic review of the literature on this topic, which was conducted recently (June 2021) (Wawrzuta et al., 2021). However, that review focused on identifying two popular themes (vaccine ineffectiveness and conspiracy theories) and limited the search to published articles and anti-vaccination messages on social media only. A more extensive review is thus needed to capture and classify the broader spectrum of anti-vaccination arguments, both on and offline.

What psychological constructs might motivate opposition to vaccination? The substantial overlap of the anti-vaccination movement with other movements that oppose science and reject evidence from scientists and researchers may offer some insight. Similar cognitive patterns are observed among opponents of vaccines and climate science, for instance, such as a tendency to endorse conspiracy theories and to strongly embrace a free-market ideology based on policies such as privatisation,

deregulation and reductions in government spending (Lewandowsky, Cook, Oberauer, & Marriott, 2013). Such beliefs have also been observed as characteristic of anti-vaccination websites, illustrating the importance of these underlying values and fundamental attitudes (Moran, Lucas, Everhart, Morgan, & Prickett, 2016).

There has been a limited amount of research that has explored the values and fundamental attitudes underlying vaccine hesitancy and opposition. Hornsey and Fielding (2017) suggested six "roots" that drive the expression of anti-science attitudes: (1) ideologies, values, and worldviews, (2) conspiratorial ideation, (3) vested interests, (4) personal identity expression, (5) social identity needs and (6) fears and phobias. The work by Hornsey and colleagues provides the departure point for our endeavour to identify the roots of vaccine opposition, although it clearly requires further refinement. For example, the root "ideology, values, and worldviews" covers a very broad range of constructs and might benefit from further differentiation into religious, moral, or political domains. In addition, there may be attitude roots beyond those described by Hornsey and Fielding (2017) that could be specifically relevant to anti-vaccination attitudes. For example, Moran et al. (2016) identified appeals to nature and a "holistic" conception of health as a frequent value highlighted by anti-vaccination websites—implicating the endorsement of alternative medicine that has been found to correlate with vaccine scepticism (Browne, 2018; Lewandowsky, Woike, & Oberauer, 2020). One of the principal goals of our taxonomy therefore is to expand and refine the set of attitudinal roots identified by Hornsey and Fielding (2017).

A hierarchy for a taxonomy of contrarian arguments

Identifying the root construct that an anti-vaccination argument taps into is challenging because the link may not be immediately evident from any individual message. For instance, it is not obvious whether a statement that "vaccines hurt people" reflects an underlying propensity to engage in conspiratorial thinking (e.g. "Bill Gates is pushing vaccines that hurt people in order to cull the population") or is expressing fear of side effects. However, if this and similar statements cluster around a theme involving fear of needles (Freeman et al., 2021), which is an aspect of the root construct "fears and phobia", then identification of the root becomes possible.

We therefore aimed to develop a hierarchical taxonomy of anti-vaccination arguments based not only on surface themes, but also involving the underlying roots of which these themes are an overt manifestation. We sought to go beyond merely synthesising existing conceptualisations; our taxonomy aimed to also elucidate the nature and structure of contrarian arguments in the antivaccination sphere and, in so doing, better understand the reasons that explain vaccine rejection among the general population. We constructed the taxonomy of contrarian arguments in an iterative process, combining both theory-driven (top-down) and data-driven (bottom-up) approaches. This selfrefining process of conceptualisation is similar to "bootstrapping operations", as described by Westen and Rosenthal (2003) in relation to construct validation:

"Initial (often vague and intuitive) theories about a construct lead to creation of a measure designed to have content validity vis-à-vis the construct as understood at that point in time. Subsequently, researchers assess the relation between the measure and relevant criterion variables and determine the extent to which (a) the measure needs to be refined, (b) the construct needs to be refined, or (c) more typically, both" (p. 609).

This methodological approach, which uses induction and deduction to move from ideas to data and back again, allowed us to:

- 1. Account for previous research on psychological constructs associated with vaccine hesitancy. A top-down approach to develop an initial taxonomy of "attitude roots", as reported in the section Description of the attitude roots identified in the scientific literature.
- 2. Describe the sets of "themes" linked to each of these attitude roots. This bottom-up approach uncovered the internal structure of the taxonomy and is reported in Study 1.
- 3. Apply the taxonomy to a large database of fact-checked and debunked contrarian arguments relating to COVID-19 vaccinations, as reported in Study 2.

In this section, we define the three levels of conceptualisation used in the taxonomy, namely arguments, themes and attitude roots. The hierarchical relations between these three conceptual layers are represented in Figure 1: attitude roots branch into sets of themes, which in turn branch into sets of arguments.



Figure 1: Conceptual hierarchy of the taxonomy of contrarian arguments.

Arguments

Arguments form the basic level of the taxonomy. People use arguments throughout their lives to convince others or themselves, and they are therefore an indispensable part of human cognition (Hahn & Hornikx, 2015). The classical definition of an argument portrays the concept as two or more propositions organized as premises and a conclusion (Walton, 1990). In this sense, an argument requires a proponent (an individual or a group), who expresses a point of view on an issue, and offers one or more reasons as support for this position. A broader definition, coming from informal logic, sees an argument as a rule-governed type of discussion entered into by two or more parties in order to resolve a conflict of opinions (van Eemeren & Grootendorst, 1984). According to this broader approach, an argument may comprise many types of speech acts that offer a supporting reason for one's opinion, including propositions but also figures, photographs, gestures and other paralinguistic communicative devices. From a psychological point of view, "arguments are invitations to inference" (Pinto, 2001, p. 169) - meaning that a person infers a conclusion from the body of evidence and adopts an attitude toward the proposition expressed in that conclusion.

It is important to distinguish arguments from other related concepts, such as rhetorical devices and fallacies. While arguments express supporting reasons for the truth of the conclusion (Hitchcock,

2007; van Eemeren & Grootendorst, 1984), rhetorical devices are subsidiary techniques aimed at making the argument more compelling, often evoking an emotional response that increases its persuasiveness (e.g. irony, metaphors, hyperbole). Although arguments and rhetorical devices are often used in conjunction, they can be distinguished because, unlike arguments, there is no logical relation between rhetorical devices and the truth value of the conclusion. Fallacies, on the other hand, constitute a subset of arguments with a flawed deductive structure (formal fallacy) or based on errors in reasoning (informal fallacy). Fallacies can have the deceptive appearance of being good arguments and, in consequence, can be persuasive. For example, the claim that "thousands of people have died after being vaccinated against COVID-19" may be persuasive even though it is fallacious because it fails to establish a causal link (e.g. thousands of people also die after drinking a glass of water). A substantial number of the arguments against vaccination can be fairly described as fallacious, but our taxonomy includes a wider scope, including arguments that, despite contradicting scientific evidence or manifesting misinformed attitudes, may be valid (i.e. not fallacious) in logical terms.

Themes

The second level of classification involves themes. Each theme clusters together a number of related arguments (from the primary level) and is in turn linked to the attitude roots (highest level of the taxonomy). Here we define the term "theme" as it is commonly used in thematic analysis, namely as "a patterned response or meaning" (Braun & Clarke, 2006, p. 82). Hence, themes constitute patterns of shared meaning across arguments. In general, themes may be established by induction; that is, identified using a data-driven approach, or by deduction; that is, identified using a pre-existing theory related to the research question (Kiger & Varpio, 2020). In the present case, we identified themes by inductive means only - that is, we did not rely on previous theory or anticipated potential themes within each attitude root. Instead, we identified themes through qualitative analyses of arguments present in the data from the past literature and from COVID-19 anti-vaccination arguments online.

Attitude roots

Attitude roots form the highest level of conceptual abstraction in our taxonomy and relate themes of arguments to psychological constructs. Following Hornsey and Fielding (2017), we defined this level of the taxonomy as "the beliefs, ideologies, fears, and identity issues that motivate people to want to reject scientific consensus" (p. 460), thus distinguishing behavioural "surface attitudes" (i.e. arguments and themes) from their respective "attitude roots", which lie beneath the surface of what people express. In other words, attitude roots refer to the psychological motives that lead people to search for, and adhere to, anti-vaccination arguments in a selective way in order to reinforce and legitimate their psychological predispositions. While arguments refer to specific sets of statements and themes refer to clusters of arguments, attitude roots typically refer to well-established psychological constructs, such as conspiratorial ideation, worldview, fear, and reactance (Hornsey, Harris, & Fielding, 2018).

Description of the attitude roots identified in the scientific literature

Following our initial top-down approach, we first identified relevant psychological constructs from the past literature known to relate to vaccine refusal. In this section, we define each of the attitude roots resulting from this literature review, also indicating the key research outcomes that motivated their inclusion in the taxonomy.

Conspiracist ideation

This root reflects a tendency to believe in conspiracy theories or engage in conspiratorial thinking (hence "ideation"). Conspiracy theories are defined as "the unnecessary assumption of conspiracy when other explanations are more probable" (Aaronovitch, 2010, p.5). The social dynamics, socio-

political background and psychological factors that predict beliefs in conspiracy theories have been widely documented, making conspiratorial ideation a well-established psychological construct (Goreis & Voracek, 2019). Lewandowsky, Lloyd, and Brophy (2018) unpacked the epistemic characteristics typical of arguments shaped by conspiracist ideation, identifying these arguments as (1) contradictory, (2) self-sealing (i.e. re-interpreting disconfirming evidence in favour of the conspiracy theory), (3) displaying a nihilistic degree of scepticism, (4) assuming nefarious intent, (5) insisting that something must be wrong, (6) self-perception of the conspiracy theorist as a persecuted victim, and (7) harbouring an inability to accept that events may occur by random chance. Previous research has confirmed that conspiracist ideation predicts anti-vaccination beliefs (Goldberg & Richey, 2020; Hornsey et al., 2018; Jolley & Douglas, 2014; Lewandowsky, Gignac, & Oberauer, 2013; Shapiro, Holding, Perez, Amsel, & Rosberger, 2016; Soveri, Karlsson, Antfolk, Lindfelt, & Lewandowsky, 2021).

Distrust

This root reflects a general mistrust in various communicators about vaccines, including (but not limited to) pharmaceutical companies, scientists, medical protocols (e.g. immunisation schedules), scientific research (e.g. efficacy of vaccines, longitudinal analyses, and data gathering), as well as a perception that politicians and healthcare professionals have vested interests and a lack of knowledge. Although related to conspiratorial ideation, arguments framed within the distrust attitude root are distinct from conspiracy theories, in that the reasons for distrust may be due to lived experience (e.g. discrimination against certain groups) and they need not express a complex causal chain of secret events. Instead, distrust often manifests as vague statements, full of suspicion and uncertainty, with conclusions drawn based on the source of the message. Previous research consistently suggests that this construct is among the strongest predictors of vaccine hesitancy (Hornsey, Lobera, & Díaz-Catalán, 2020; Jolley & Douglas, 2014; Lee, Whetten, Omer, Pan, & Salmon, 2016; Salmon et al., 2005; Soveri et al., 2021; Tram et al., 2021).

Unwarranted beliefs

This root captures a variety of beliefs that are not backed up by science, misrepresent scientific facts, or are based on pseudoscientific conceptions. Pseudoscientific conceptions can take on a range of beliefs, such as endorsement of alternative medicine, that "natural" is always better, or that vaccines overwhelm infants' immune system. Prior research has shown that the nomological network of these unwarranted beliefs are shaped by cognitive variables, such as an intuitive cognitive style (Pennycook, Cheyne, Seli, Koehler, & Fugelsang, 2012), ontological confusions (Svedholm & Lindeman, 2013), poor scientific literacy (Fasce & Picó, 2019), pseudo-profound bullshit receptivity (Hart & Graether, 2018), and causal illusions (Torres, Barberia, & Rodríguez-Ferreiro, 2020). The pivotal role of cognitive variables differentiates unwarranted beliefs from conspiracy theories, which are primarily influenced by intergroup and emotional variables (Pierre, 2020; van Prooijen, 2019). These unwarranted beliefs, for example regarding the "natural healing potential" of the body (Browne, Thomson, Rockloff, & Pennycook, 2015) and the use of alternative medicine (Bleser, Elewonibi, Miranda, & BeLue, 2016; Soveri et al., 2021), have also been repeatedly linked to negative attitudes toward vaccination.

Worldview/politics

This root stems from an individual's particular view on how society should be organised, including well-documented predictors of vaccine rejection such as populism (Kennedy, 2019), nationalism (Lewandowsky & Oberauer, 2021; Whitehead & Perry, 2020), conservatism (Motta, 2021), and individualistic/hierarchical worldviews (Hornsey et al., 2018), as well as views on issues related to the specific political context of each country, such as animosity toward a particular government, political party or politician. Studies on vaccine hesitancy often highlight its political dimension, especially in relation to conservatism – possibly because these political factors are prone to come into conflict with

the nature of scientific inquiry and scientific theories that pose a threat to certain moral conceptions (e.g. evolution) and financial interests (e.g. climate change; Lewandowsky & Oberauer, 2021; Rekker, 2021).

Religious concerns

This root encompasses a wide range of religious beliefs and norms that have been shown to motivate hesitant attitudes toward vaccination (Grabenstein, 2013). These concerns can be divided into four groups. First, violations of dietary norms, such as blood components and pharmaceutical excipients of porcine or bovine origin. Second, moral concerns about the use of cell lines with foetal origins and sexual taboos (e.g. HPV vaccinations protect against a sexually transmitted disease). Third, defence of the natural order by letting events take their course, such as rejection of interference with divine providence. Fourth, religious alternatives to vaccination, such as faith or prayer to fight diseases. This root only accounts for contrarian arguments based on theological objections, thus leaving aside sociopolitical arguments raised by fundamentalist groups (e.g. opposition to vaccination campaigns promoted by Western countries) or related to conservative lifestyles (e.g., rejection of technological advances). Despite the fact that religiosity does not predict greater hesitancy at the international level (Eriksson & Vartanova, 2021), vaccination rates are particularly low among some religious communities (Barskey et al., 2012; Bodson, Wilson, Warner, & Kepka, 2017; Hanratty et al., 2000), and some misinformation around vaccines is known to target specific religious concerns.

Moral concerns

This root stems from an individual's sense that vaccines are contrary to their moral stance, mainly because the individual perceives vaccines as promoting immoral behaviour and/or being developed using immoral means. This root is distinct from religious concerns in that although morality may stem from religious beliefs, one does not have to be religious to maintain a specific moral position–for example, many people oppose abortion on a moral basis, without appealing to religious beliefs. Morality concerns about vaccines often manifest as worries about a permissive environment for girls to engage in sexual activity (especially in relation to the human papillomavirus – HPV – vaccine), the use of foetal cell lines, non-consensual experiments in adults and children, and animal mistreatment during vaccine development and production, and/or resistance to the idea that universal vaccination sacrifices a few to benefit many (i.e. anti-utilitarianism). Several studies have confirmed the predictive power of moral values and foundations for vaccine rejection (Amin et al., 2017; Rossen, Hurlstone, Dunlop, & Lawrence, 2019).

Fear and phobias

This root captures the different fears that lead individuals to reject vaccines. Individuals often prefer to take a stance that enables them to avoid their fears than to confront their lack of control over the fear or the associated negative self-perception from having an irrational phobia (Hornsey & Fielding, 2017). Irrational vaccination fears, which are disproportionate to existing dangers, are usually of two types. One involves fears related to suffering side effects, such as autism, cancer, autoimmune diseases, neurodevelopmental disorders or even death due to overload of immune system or presumed ingredients of vaccines that are perceived as toxic (e.g. formaldehyde, glycerine, thimerosal, and aluminium). The other involves fear of the procedure: for example, individuals suffering from trypanophobia experience symptoms of extreme anxiety or vasovagal syncope in face of medical procedures involving hypodermic needles. Prior research has shown that both fear of side effects (Karlsson et al., 2021; Salmon et al., 2005) and trypanophobia (Freeman et al., 2021; Hornsey et al., 2018) predict vaccine hesitancy.

Distorted risk perception

This root is closely related to the Complacency factor of the 5C model for the psychological antecedents of vaccination (Betsch et al., 2018). In this context, distorted risk perception stems from a lack of fear and/or awareness of the threat posed by the disease, either to oneself or to others. Individuals perceive that the disease is of low or inconsequential risk, and this motivates their belief that vaccination is unnecessary or that the drawbacks outweigh the benefits. This root accounts for arguments such as that vaccines are only for developing countries or unhealthy people, or that certain vaccines are not necessary because they prevent minor diseases. Risk perception has been found to be a good predictor for hesitant attitudes toward vaccination (Caserotti et al., 2021; González-Block et al., 2020; Karlsson et al., 2021; Kwok et al., 2021).

Selfishness

This root stems from a prioritisation of one's own needs relative to that of others. It can be understood as the opposite of collective concern or prosociality, in that the motivation is for others to contribute to herd immunity in order to protect the selfish individual, in effect wishing to freeride on herd immunity. Sometimes, this root manifests also in the defence of alternatives to vaccination that are only available to people with a high socioeconomic status, such as lockdowns or jobs in low-risk sectors. Selfishness is closely related to an individualistic and competitive worldview, in which individuals must look out only for themselves and their children, which would most strongly predict hesitancy for oneself, but when such arguments spread, has the capacity to undermine herd immunity. Even though peer influence tends to dominate freerider motives (Verelst, Kessels, Willem, & Beutels, 2021), free-riding behaviour has been observed in experimental studies (Betsch, Böhm, & Korn, 2013; Hershey, Asch, Thumasathit, Meszaros, & Waters, 1994; Ibuka, Li, Vietri, Chapman, & Galvani, 2014).

Epistemic relativism

Epistemic relativism is the view that the concept of "truth" and its associated standards of reasoning (e.g. critical thinking, scientific methods and evidence-based decision making), are products of conventions and frameworks of assessment (e.g. historical contexts, social and cultural norms, and individual standards), so there can be no framework-independent point of view from which to obtain objective knowledge (Boghossian, 2006; Kusch, 2021). This root encompasses a broad spectrum of forms of relativism, including postmodern understanding of scientific truth and expertise, prioritisation of subjective experiences over the nomological forms of reasoning typical of scientific studies, appeals to "maternal intuition", and invitations to "do your own research" to outweigh scientific evidence. Empirical research has linked several forms of epistemic relativism with vaccine scepticism (Browne et al., 2015; Reich, 2014; Schindler, Schindler, & Pfattheicher, 2020; Ten Kate, De Koster, & Van der Waal, 2021; Tomljenovic, Bubic, & Erceg, 2020).

Reactance

Reactance is a long-standing psychological construct, which has been consistently associated with vaccine hesitancy (Finkelstein et al., 2020; Hornsey et al., 2018; Soveri et al., 2020; Sprengholz, Betsch, & Böhm, 2021). Reactance is defined as an individual's tendency to defend their autonomy when they perceive that others are trying to impose their will on them. Accordingly, this root includes a defence of civil liberties, in which the individual is motivated by claiming their right to act contrary to social norms and politics. This is related to a high sense of personal autonomy and empowerment, where patients react to health advice as an infringement on their ability to choose an action for themselves. Reactance manifests in arguments that oppose vaccination mandates, proclaiming that the decision whether or not to vaccinate must be completely free and autonomous. Other elements of reactance include the claim that communication between patients and health care professionals must be on an

equal footing, and that vaccination must not bestow any favorable treatment upon persons (e.g. the right to travel, enrol in an educational centre, or attend social events).

Study 1: Systematic literature review

Having established a set of roots for the top level of our hierarchical taxonomy, we next conducted a systematic review of the literature to harvest existing knowledge about anti-vaccination arguments. That is, instead of analysing the "raw material" on anti-vaccination websites and social media, we relied on the considerable body of existing research to collect arguments and themes for inclusion in our taxonomy. The purpose of this first study was to conduct a data-driven thematic analysis for each attitude root identified in the initial, top-down phase, thus enriching the taxonomy and facilitating a more systematic understanding of the arguments accounted for by each attitude root.

The review followed the PRISMA protocol for systematic reviews (Page et al., 2021) and was preregistered prior to data collection. The preregistration can be found at https://osf.io/e4yp6/ along with the data extraction sheet with the full set of data sources: Figure 2 contains a flowchart of the PRISMA protocol and its implementation in the present study.



Figure 2: Article collection process, including the number of articles identified and excluded at each stage of the process.

Method

Search and selection strategy

We searched the following scientific search engines, selected for their coverage of the relevant literature (e.g. psychology, health studies and argumentation) and their ability to satisfy relevance, transparency, and reproducibility criteria in systematic search (Gusenbauer & Haddaway, 2020): Scopus, Web of Science, PubMed, and PsycInfo. The search was also extended to three preprint servers relevant to the field: PsyArXiv, ArXiv, and MedrXiv. These databases were added to accommodate the large number of articles on anti-vaccination attitudes that are expected to be in process at the time of the pandemic.

We used the following search string to encompass the different variations in terminology used in the literature:

("vacc* refus* " OR "anti-vacc* " OR "anti-vax* " OR "vacc* oppon* " OR "vacc* oppos* " OR "vacc* skeptic* " OR "vacc* sceptic* ") AND (trope* OR meme* OR narrative* OR argumen* OR theme* OR rhetoric)

Guided by previous research on vaccine refusal we included terms that relate to the concept of antivaccination attitudes (e.g. "vaccine skeptic", "vaccine opposition").

Furthermore, we used terms related to the concept of arguments and themes (e.g. "tropes", "rhetoric"). Thus, the search results included articles related to vaccine refusal and articles that focused on arguments or themes. This search logic was adapted to the characteristics of each search engine as needed. Specifically, the Boolean logic represented by our search string exceeded the capability of some search engines, for example preprint servers, such that we had to replicate the logic via partial repeated searches.

The search was conducted on 1 July 2021. Articles were included if they were published in peerreviewed journals or on scientific preprint servers in English and reported analyses of anti-vaccine statements in public circulation (e.g. on a website, social media, blogs, etc.). We defined "analyses" broadly, including descriptive analyses, conceptual and philosophical analysis, historical studies, text modelling, and so on. We excluded studies focusing on vaccination of non-human subjects, reporting only raw data (e.g. tweets with no further conceptualisation of their contents), and vaccine mandates. We excluded mandates because they constitute a socio-political issue whose resolution is not based on scientific evidence. Specifically, one can reject mandates irrespective of one's attitudes towards vaccines—both vaccine acceptance and vaccine rejection are compatible with opposition to mandates. We did not restrict the search to a specific time period and thus included articles published before 1 July 2021.

Coding of articles and data extraction

First, the deduplication tool by Zotero was used to identify duplicates in the final sample. All duplicates were checked manually and deleted from further analysis. Two reviewers independently reviewed the title and abstract of the resulting articles to categorise them as "relevant", "not relevant", or "uncertain" with regard to exclusion criteria. The reviewers discussed discrepancies after independent ratings and consulted a third reviewer if discrepancies could not be solved. After title and abstract scan, two reviewers reviewed the full text of the final set of articles that were determined to be relevant and categorised them as "accept", "reject", or "uncertain". Again, reviewers discussed discrepancies and proceeded when consensus was reached. For all articles rejected at this stage, the reasons for rejection were recorded and uploaded to the open repository at https://osf.io/e4yp6/.

Finally, the following content data were extracted from each article accepted for inclusion in the review:

- Author
- Year of publication
- Title
- Journal/preprint server
- DOI/URL
- Content platform: the platform(s) or channel(s) studied. Common platforms included: websites, Twitter, Facebook, YouTube.
- Content type (as described by article authors): the individual articles' authors' terminology of the tropes or rhetorical strategies reported. Common terms used were "tropes", "themes", "narratives", "tactics", "strategies".
- Sample origin: the country or language area from which the article's sample was drawn.
- All arguments identified in the article.

Results

Identified literature

Overall, 816 articles were identified using the outlined search strategy (see Figure 2). The Zotero deduplication tool identified 320 duplicates that were removed from further analysis. The resulting 496 articles (379 journal articles and 117 preprints) were deemed eligible for title and abstract scan. 301 records were coded as irrelevant and were removed at this stage, leaving 195 articles for full text search. If access to papers was denied via institutional accounts then we contacted the authors. Six articles could not be accessed online or via the authors within a week of the request. Thus 189 full text papers were scanned and 37 of them dropped for specific reasons (see Figure 2). The final set contained 152 articles (peer-reviewed: n = 149; preprint: n = 3).

Descriptive analysis of articles

The final 152 articles cover a wide time span, with articles published between 1967 and 2021. However, research interest in arguments of vaccine refusal has experienced a considerable increase in recent times, with about 50 percent of all articles being published after 2018. The articles also cover a wide range of cultural diversity in terms of origin of samples. While most samples were from the U.S., UK, Canada and Australia, the samples from 117 of the 152 articles were drawn from 47 different countries (Figure 3), while 22 articles gathered data from international samples of English speakers and 3 gathered data from samples of French speakers (missing n = 10). Thus, the samples for the final selection of arguments and themes are transcending various cultural backgrounds. The diversity of findings is also represented by the number of different platforms that were used to analyse arguments of vaccine refusal across the final articles. The origins of samples range from social media (e.g. Twitter, YouTube, Facebook), movies (e.g. Vaxxed) and anti-vaccination websites to qualitative interviews with physicians or members of the general public. This diversity ensures that the selection of arguments and themes are wide range of public discourse.



Figure 3: Country of origin of the samples reported in the final set of articles obtained from the systematic review

Identification of attitude roots

We extracted 1,296 arguments against vaccination from the final set of 152 articles that form our argument corpus. Authors usually presented arguments at two levels: First, concrete arguments (e.g. "it just encourages unsafe sex"; specific level), and second, proposed conceptualisations to summarize those concrete arguments (e.g. "sexual promiscuity" abstract level). Not all arguments included specific-level examples.

These arguments thus constitute the summary of information relevant for this review. Four reviewers first assessed the extracted arguments (both at the specific level when present and the abstract level), to independently identify the attitude roots underlying each argument (e.g. "sexual promiscuity" was framed within the "moral concerns" root). Some arguments were classified into two or more attitude roots, considering that there was a dominant root and subsidiary ones [e.g. if an argument established a link between the HPV vaccine and sexual promiscuity from a religious perspective (premarital sex as a sin), we considered religious concerns to be the dominant root, with a subsidiary assignment to moral concern]. The reviewers then met to discuss any discrepancies and to reach consensus about the attitude root(s) that characterize each argument, striving for a consistent classification, with well-founded and recursive patterns.

Subsequently, we calculated the frequency of root assignments in the argument corpus in two ways. As articles varied in terms of how they presented the arguments, with some authors mentioning many different arguments all referring to one root in the same paper, whereas others summarised the arguments as one broad category, we first counted the number of times each argument was assigned to the various roots across all articles, allowing multiple arguments for each article. We then counted each root only once per article and summed the mentions across articles. Although the proportion of assignment to each root differed slightly between the two calculation methods, the ranking of roots in terms of their frequency remained virtually unchanged. As can be seen in Figure 4, all roots were identifiable within the corpus, although their relative prevalence differed considerably. The top three (counting mentions per article) were Distrust (18.3%), Fears and Phobias (17.7%), and Unwarranted Beliefs (13.6%).



Figure 4: Attitude root frequencies among academic articles. Total count of roots (in dark blue) and each root counted once per article (in light blue)

Word frequencies and word clouds

To illustrate the content of the arguments associated with each root, we constructed word clouds to describe the arguments for each of the 11 roots. For each root, we obtained two collections of words: First, we considered all text across both levels of argument classification together, and second, we considered the "raw" text that represented verbatim quotes from the literature.

Following standard text modelling procedure (e.g. Garcia, Goel, Agrawal, & Kumaraguru, 2018; Li, Hills, & Hertwig, 2020), we removed stop words (such as "the" or "are") that are considered unimportant for text analysis. Here we identified stop words using the SMART option for R package *tm*. We also removed non-alphabetic material. In addition, we removed the words "vaccination" and "vaccines(s)" because they (a) occurred in all roots and (b) were so frequent that they dominated the word clouds, largely obscuring the underlying pattern.

The resulting word clouds are shown in Figures 5 through 7. Up to 70 of the most frequent words are shown, and words that occurred once only are excluded from consideration. The word clouds illustrate the rhetoric underlying each root and confirm the assignment of arguments to roots. For example, the word clouds for unwarranted beliefs highlights terms such as "natural" and "immunity", and "alternative" or "hygiene" that reflect the common elements about anti-vaccination arguments based on belief in the body's own immune system.

Conspiracist ideation



Distrust



Unwarranted beliefs

superior influenza autralia superior influenza sinalipox nutrition medicai numbermeasleschildhood youngnature alternative children disease ္ခ ebola better breastfeeding immunization betterdise child illness grmultiple es herd a rather can many vaccinated health ល_{immune} Nta system 5 risk medicine body effective rate do emor hygiene hygiene Thealthyexen DD ssary

Worldview/politics



Figure 5: Word clouds for the roots conspiracist ideation, distrust, unwarranted beliefs and worldview. Each word cloud is created using the two levels of arguments (specific and abstract) extracted during analysis.

Religious concerns

Moral concerns



Fears and phobias



Distorted risk perception



immunizing

Figure 6: Word clouds for the roots religious concerns, moral concerns, fears and phobias, and distorted risk perception. Each word cloud is created using the two levels of arguments (specific and abstract) extracted during analysis.

Selfishness

Epistemic relativism



 totalitarianism immunity
 >

 Figure 7: Word clouds for the roots selfishness, epsistemic relativism, and reactance. Each word cloud is created using the two

make

levels of arguments (specific and abstract) extracted during analysis.

accinate bodily violation public

Thematic analysis

We next conducted a thematic analysis of all anti-vaccine arguments in our argument corpus (Braun & Clarke, 2006; Nowell, Norris, White, & Moules, 2017). For each attitude root, coders grouped the arguments assigned to that root into common themes.

This was an iterative coding process, in which coders developed initial themes as they began to code the arguments, which were then modified throughout the coding process and re-applied to the initial arguments. Two coders performed the analysis independently, and a third researcher reviewed their themes for commonalities. All three researchers reached a consensus on the themes through discussion. The final list of themes found in the systematic literature review data is explained in Table 1, organised by attitude root. The table also reports sample arguments from the corpus. In addition, the table lists a synthetic prototypical argument for each theme that was created by three reviewers to represent the "essence" of the arguments in the corpus for that theme. The prototypical arguments

will be used in subsequent work packages in JITSUVAX for a variety of purposes, such as persuasiveness ratings and to create rebuttals or inoculation messages.

The information in Table 1 represents the desired taxonomy of anti-vaccination arguments. Unlike previous research, the taxonomy is linked to attitudinal roots and it is based on a systematic review of the existing literature rather than analysis of raw data (i.e. information gathered directly from anti-vaccination discourse online or on social media). The accuracy of the assignment of arguments to roots was visually confirmed by the word clouds (Figures 5 through 7). The assignment to roots presents a novel and unique contribution of our taxonomy. Another novel aspect of our taxonomy is that it spans several decades of research on anti-vaccination argumentation – this historical integration could not be obtained by harvesting contemporary social media which is likely to be quite ephemeral.

These novelties and advantages do however come at a cost. First, the taxonomy extends across many different vaccines as well as across time, which enhances generality but at the possible expense of losing the ability to accommodate and pinpoint unique situations. Specifically, although COVID-19 vaccines were included in the systematic review and resultant corpus, these new vaccines were explicitly addressed in only 14 out of the 152 articles retained for analysis. It therefore remains to be seen how well the taxonomy in Table 1 extends to the specific contemporary circumstances. A second potential problem is that the taxonomy was based on analysis of the existing literature, rather than direct harvesting and analysis of content. This indirect approach maximizes knowledge gain–because it builds on all available prior work rather than trying to "reinvent the wheel"–but it also introduces a layer of potential mediation or distortion.

Although we consider it highly unlikely that the 152 scholarly articles we analysed, which were published by independent teams of authors, would introduce a systematic distortion of the landscape of argumentation, we cannot rule out that possibility. Our second study therefore endeavoured to address both of those potential problems.

Table 1. Themes of anti-vaccination arguments identified for each attitude root.

Root	Theme	Explanation of theme	Arguments (examples)	Prototype argument (for persuasiveness rating)
Conspiracy ideation	Government conspiracy/ cover up	This theme relates vaccines to governments/governmental/state agencies or pharmaceutical companies, doctors, CDC/WHO, or the media, conspiring to lie, cover up/hide, or withhold important information about vaccine dangers/adverse side effects from the public. It often co-occurs with the "financial gain" theme, where sometimes the cover-up is about hiding links to pharmaceutical companies/being in cahoots with them and hiding it from the public. However, conspiracist arguments about a cover up may occur without linking it to a profit motive.	Important facts had been overlooked or, even worse, covered up by the medical establishment. Argues that vaccination is a conspiracy. Includes accusations that vaccines are fake or governments lie about them.	The authorities are lying and covering up important information about the vaccine.
	Profit over people	This theme claims vaccines are a conspiracy by "Big Pharma" or medical, pharmaceutical/drug, regulatory, and/or health organisations (including doctors) in order to profit, test new drugs, make money/sales, and supporters of vaccines are in the pocket of or hired by these organisations. It often co-occurs with the "government conspiracy/cover up" theme, where the financial incentives are covered up/lied about or the cover up of vaccine dangers is to support profit motives. However,	Hired gun for ``Big Pharma" Some conspiracies of making money out of people.	<i>"Big Pharma" is colluding with the medical authorities to profit from people getting vaccinated.</i>

Root	Theme	Explanation of theme	Arguments (examples)	Prototype argument (for persuasiveness rating)
		financial gain can occur as an argument without claiming there is a cover up.		
	Population control	This theme claims that the vaccine is a way to keep the population under control. There are two variants:		
		(a) control of population numbers or "depopulation" (i.e. genocide), e.g. by weaking people, causing infertility, sterilisation, acting as birth control, using bioweapons;	Preparing the population to be organ donors.	The vaccine is a way to control population numbers.
		(b) control or tracking of behaviour, e.g. by installing microchips, causing dependence on medication, creating a "New World Order"; this variant often refers to Bill Gates as the instigator.	Perceived government intervention that was not true, such as the government using vaccines to insert microchips and governmental vaccine use for population control.	Some vaccines contain microchips that will be used to control us.
	Exaggerated/ made up threat	This theme claims that the disease the vaccine treats has been exaggerated or does not exist, often calling it a "hoax" or "fabricated" and accusing governments of spreading fear.	Certain diseases, such as polio, do not actually exist. The ongoing outbreak was fabricated by politicians to destabilize the eastern part of the country.	To get us vaccinated, medical authorities are spreading fear about diseases that do not exist or are fabricated.
	Targeting ethnic groups	This theme perceives the vaccine as a conspiracy to target certain ethnic groups or weaker countries, regarding it as a "war" on	Vaccination campaigns in poor countries are sham actions organized by hostile foreign	Vaccination campaigns are targeted at weakening

Root	Theme	Explanation of theme	Arguments (examples)	Prototype argument (for persuasiveness rating)
		these groups – in some cases related to a Jewish plot targeting Muslims/Islam.	states that collect intelligence, or weaken people living in a given area (rumours of this type have been spread in Africa and Pakistan). Race extermination conspiracy	disadvantaged groups, minorities, and poor countries.
Distrust	Incompetent/ uncompassionate healthcare	This theme addresses the healthcare system and the medical profession, such as doctors, due to the perception that they are incompetent (e.g. unknowledgeable, negligent, untrained) or uncompassionate (e.g. paternalistic, ignorant, judgemental, disinterested, unfriendly, motivated by profit, conflicts of interest), often citing previous bad experiences and relationships. Distrust is accompanied by a preference for dissenting healthcare professionals.	Expressed concern about the training and individual expertise of GPs. They felt mistrust when their physician was unavailable or when pressure was exerted on them to accept a suggested medical treatment or procedure.	When it comes to vaccines, doctors do not know what they are doing and do not care about patients.
	Distrust of vaccines	This theme is focused on distrust related to the vaccines themselves, where they are perceived as suspect for a number of reasons, including that:		
		(a) they are experimental, new, and untested, with unknown long-term effects, and were fast-tracked such that the population are unwilling guinea pigs or that vaccines were experimental for certain ethnic groups;	Children are being experimented on.	The vaccine is new and untested, and I am not willing to be part of an experiment.

Root	Theme	Explanation of theme	Arguments (examples)	Prototype argument (for persuasiveness rating)
		(b) their efficacy is doubted, often due to misunderstanding of science and statistics;	The broken promises of the vaccinators for life-long protection.	Research on vaccine safety is based on biased or incomplete data.
		(c) they cause harm, often due to belief in misinformation peddled by inauthentic experts or sources.	<i>Vaccines are dangerous and adverse events cannot be calculated.</i>	
	Distrust of science	This theme is focused on distrust of the scientific process behind vaccine development, including claims that science was manipulated and biased, and cherry- picking of facts to support suspicions.	Critiquing biomedicine/Germ- Theory. Scientific controversy over the benefits of vaccination in	The alleged scientific studies on vaccines are based on discredited theories and flawed methodologies.
	Exaggerated risk	This theme incorporates distrust about official statistics and coverage of the disease, believing there to be a false panic, little risk, or that medical authorities are overreaching and trying to treat even minor illnesses with vaccines that are unnecessary and a distraction from more important problems.	Concern that vaccination provision in Scotland does not include children being examined pre-immunisation by health staff, and that children with a cough or cold may be vaccinated. Vaccination does not seem a relevant problem to people when they have unmet basic medical and nutritional needs.	Medical authorities are overreacting, with vaccines being recommended for every minor illness now.
	Distrust in private companies	This theme addresses the distrust of pharmaceutical companies, who are not trusted to put people's safety over	The statistics by the advocates of vaccination were not reliable since they were piled by those	Information from "Big Pharma" about vaccines is not to be trusted.

Root	Theme	Explanation of theme	Arguments (examples)	Prototype argument (for persuasiveness rating)
		profits/financial gain. Overall, there is distrust wherever a financial motivation is perceived.	with a financial interest in the continuation of the operation.	
			Collusion: Vaccine promoters benefit from illnesses caused by vaccines.	
	Systemic corruption	This theme perceives that the healthcare and government systems, including politicians, doctors, health agencies, celebrities, and the media are untrustworthy because they are corrupt and in cahoots with pharmaceutical companies, have conflicts of interest, and/or are biased and deceiving the people. It follows on to describe science as corrupted by the system and therefore untrustworthy, and proper open debate is needed and we should question the motives of healthcare providers.	Outright deception in the promotion of HPV immunisation. Personal data collected could be transferred to other agencies.	Healthcare authorities, politicians, and governments are corrupt and profit from vaccinations.
	No accountability or regulation	In this theme, distrust stems from a perceived lack of accountability, where companies and healthcare providers are not liable for "vaccine damage", authorities display a lack of transparency about vaccine- related decisions, regulation is either lacking or poor, and doctors/HCPs/politicians do not appear to lead by example in having a vaccine themselves.	No one is responsible for the potential side effects of the vaccine. Distrust in the organisations responsible for vaccine promotion and regulation; belief that vaccine safety testing is inadequate, flawed or biased.	There is not enough safety testing, and no one is liable if someone is harmed by the vaccine.
	Oppressive outgroups	This theme reflects a general source distrust, where there is a suspicion of those considered	Trust in social network.	Powerful groups oppress disadvantaged groups and

Root	Theme	Explanation of theme	Arguments (examples)	Prototype argument (for persuasiveness rating)
		as belonging to an (usually oppressive) "outgroup", with the individual only trusting their community and social networks.	Perception of oppression and inequalities (women, Blacks, LGBTQ, indigenous people).	genders by imposing vaccination.
	"Do Your Own Research" (DYOR)	This theme discusses the need to be sceptical and "find out for yourself" instead of trusting the words of doctors, physicians, media, the government, etc., who only give biased information. Only one's personal research is to be trusted, so individuals may invoke wanting to find out information for themselves and not be rushed into decisions. The theme characterises people who don't do their own research but listen/trust these authorities as lazy and uninformed and invokes individual exceptionalism as the rationale for needing to research a personal decision.	Not having enough time to learn, do research, make a decision. Reliance on this vaccine (or all vaccines) represents poor (lazy, uninformed) parenting.	People should do their own research and decide rather than following so-called "experts".
Unwarranted beliefs	Complementary Alternative Medicine (CAM)	This theme advocates for CAM as an alternative to vaccines that is as effective or superior for treating or preventing the disease, including remedies such as homeopathy, chiropractic, nosodes, energetic dose, naturopathic, vitamins, essential oils, acupuncture, plant extracts, morphogenetic field, faith and pray healing, misalignments, and other forms of "alternative health".	While homeopathic hospitals had had a death rate of "1% or fewer," conventional hospitals had reported a death rate of "2.5 to 1%." Plant extracts, 'biopuncture', ultraviolet blood irradiation, acupuncture, Vitamin C & D, herbs, 'immune booster shots', etc.; homeopathy; [naturopathy].	Vaccines are not as good as traditional and natural remedies, such as homeopathy, which have a similar record of healing and no side effects.

Root	Theme	Explanation of theme	Arguments (examples)	Prototype argument (for persuasiveness rating)
	"Natural is best"	This theme advocates for the superiority of a natural/holistic approach to disease treatment and prevention and rejects vaccines on the basis that they or the immunity they produce are "unnatural" or "poison" that harm the body or interfere with natural immunity. Treatments advocated include acquiring natural immunity against the disease, boosting one's immune system and innate healing through healthy and organic lifestyles or CAM practices. Arguments often appeal to pseudo- or quasi-scientific terms such as "true molecular imprint", "nosodes", and "morphogenetics" or alternative lifestyle values such as "organic", "detox", and "natural".	Prioritize natural immunity against measles. Vaccination interfered with the natural immunity acquired from breastfeeding.	Vaccines interfere with the body's natural immunity, which is a better defense against the disease.
	"Too much medicine"	This theme claims that vaccines are overloading or overwhelming our immune systems (particularly for children/babies/infants), and argues that people are getting vaccines too young, too soon, or having too many, in some instance citing pseudoscience about the "blood brain barrier". In extreme forms, it rails against Western healthcare systems and lifestyles as a "tyranny" and "oppression" that advocates overconsumption of medicine and damages fragile communities.	Children are already receiving many vaccines. Taking too many vaccines overloads immune system	People are being offered too many vaccines nowadays, and this will overload their immune systems.

Root	Theme	Explanation of theme	Arguments (examples)	Prototype argument (for persuasiveness rating)
	Other ways to avoid disease	This theme claims that at best, vaccines are unnecessary because there are other ways one can avoid diseases or severe symptoms such as behavioural measures (e.g. sanitation, quarantine, hygiene), lifestyle choices (e.g. exercise and nutrition, cleanliness, organic food, GMO-free, vitamins, less toxins, herbs, essential oils), and personal responsibility (e.g. preventing exposure, being careful); at worst it is an "expensive distraction" from these better disease-prevention methods and also distract from other important things we should focus on, such as "self-care" and "nurturing children" or other philosophical questions we should answer. This theme does not necessarily advocate naturalistic treatments but could include them as well.	Lifestyle choices as substitutes for vaccines. Attributing improvements in health over recent decades to factors other than vaccines (e.g. better sanitation, cleaner water, and less crowding).	Instead of vaccines, people should improve environmental factors like good hygiene, healthy lifestyles, and protective measures against the disease.
	"Science is not settled": denial of immunological consensus	This theme argues against science (implicitly supporting unwarranted beliefs) by claiming that we must debate the scientific consensus around vaccines, pointing to controversy or disagreements among scientists, and uncertainties or unknowns as evidence that belief in the scientific process behind vaccines is unwarranted.	Herd immunity is a theory that has never been tested. Scientific controversy over the benefits of vaccination in general.	Scientists are still debating the benefits of vaccination, and the science is not settled.
	Belief in misinformation	This theme captures a belief in misinformation that is commonly spread about vaccines, such as the myths that vaccines cause diseases, allergies, and other harms, that vaccines	Pertussis vaccine increases the risk of asthma by six times.	Vaccines contain viruses and can cause the disease they are supposed to prevent.

Root	Theme	Explanation of theme	Arguments (examples)	Prototype argument (for persuasiveness rating)
		contain active viruses or other toxic contaminants, and that vaccines are ineffective.	Believing influenza vaccine leads to influenza.	
	Vaccinated as "other"	This theme encapsulates the belief that people who are vaccinated are different and dangerous, considering them to be less healthy, spreading disease and making others sick, and behaving irresponsibly (e.g. not taking precautions).	Vaccinated people spreading diseases that they have gained immunity to. Unimmunised children are healthier.	Vaccinated people spread the disease they got vaccinated against, making the healthy and unvaccinated sick.
	Fallacious logic	This theme attacks science/vaccines using fallacies such as the impossible expectation placing the burden of proof that vaccines are harmless on the medical community, making unwarranted causal attributions because coincidences are not possible, and misusing statistics.	You can't prove vaccines are safe: Demanding vaccine advocates demonstrate vaccines do not lead to harm, rather than anti-vaccine activists having to prove they do. When Japan raised their vaccination age, from two months to two years in 1975, the rate of Sudden Infant Death Syndrome (SIDS) dropped from 13th in the world to becoming the lowest.	It cannot be a coincidence that when vaccination rates increased, so did case rates and death rates.
	Other pseudoscientific beliefs	This theme encompasses non-specific unscientific beliefs in alternatives to vaccination, such as one's "own research", faith healing, personalised medicine, and	When someone is exposed to multiple toxins simultaneously, toxicity levels and adverse side effects increase exponentially, as opposed to when the individual	The disease will disappear on its own, following a natural cycle.

Root	Theme	Explanation of theme	Arguments (examples)	Prototype argument (for persuasiveness rating)
		magical thinking (i.e. the disease will "disappear" by itself).	toxins in vaccines are tested separately in isolation.	
			Mortality and morbidity would decrease spontaneously, even if vaccines were not applied.	
Worldview	Science is elitist	This theme taps into a populist worldview and casts science and scientists as belonging to an elite group that is set against the people/population and maligns, for example, ordinary people. Vaccine inequality springs from this theme, arguing that vaccines result in new health disparities.	A "profound distrust in elites and experts" is intimately associated with populist politics. Cultural stereotypes that portrayed the working class as the locus of disease.	Vaccines are just another way that the scientific elite are widening inequalities and subjugating ordinary people.
	Libertarianism	This theme appeals to the idea of "civil liberties", "personal freedom and choice", and reflects a worldview that one's personal choice should not be infringed upon by overreaching states excessively exercising or abusing their power/ authoritarianism/ totalitarianism. This worldview places importance on an individual and is also related to the moral anti-utilitarian stance that individuals should not be sacrificed for the greater good.	Vaccination as a socialist policy. Authoritarianism/abuse of power by doctors or the State.	Vaccinations are an expression of the inappropriate interferenc of the state in the freedoms of individual citizens.
	Science has an agenda	This theme claims science cannot be objective and always has a political or economic agenda, or that politics influences science so it cannot be trusted. Arguments are often made against	The social practice of science– despite claims of objectivity– reflects a political or economic agenda.	The science for vaccination is shaped by political agendas.

Root	Theme	Explanation of theme	Arguments (examples)	Prototype argument (for persuasiveness rating)
		these perceived agendas, for example, standing against the economic burden of vaccines, or the politicians who advocate vaccines.	No research has been conducted concerning the long-term effects of vaccinations and that the lack of such studies is linked to both the political and economic agendas of the pharmaceutical industry and government.	
	Traditional culture	This theme talks about conservative social and ethnic cultures and how vaccination does not fit with the culture and its social norms, is not for the community, and is going too far (departing from these conservative morals). It places those outside the culture as an outgroup that is not like them (usually less healthy).	The vaccination drive did not conform with the conservative Pashtun culture. Keeping in view the patriarchal structure of the society, there is a natural liking for male children, and hence this cultural preference plays into vaccine refusals.	Adhering to one's own traditional, cultural rules is more important than following vaccination guidelines.
	Political concerns	This theme reflects political concerns and points to specific government or regulatory (in)actions.	Politicians threatening the US Food and Drug Administration to rush vaccine approval. Vaccination to delay elections or destabilize parts of a country.	Politicians use vaccinations as strategies to boost their own political agendas at the expense of the common good.
	Rejection of technology and modernity	This theme comprises arguments raised by certain groups that reject modern practices, such as Mennonites (e.g. Amish and Hutterites) and Haredi Jews. Although immunisation is not directly prohibited by	Districts that typically decline immunisation reflect a social tradition within these religious communities, related to	Vaccines are a modern invention and I try to avoid modern technology as much as possible.

Root	Theme	Explanation of theme	Arguments (examples)	Prototype argument (for persuasiveness rating)
		their theological conceptions, these communities practise a lifestyle that avoids modern technology–including medical	modernity, more than a theological objection.	
		advances like vaccines.	Illness is no longer tolerated in modern society due to its inconvenience.	
Religiosity	Impurity	This theme targets vaccines' use of materials that are prohibited/considered impure by the	Violation of dietary laws	Vaccines contain products that are forbidden by my religion.
	religion bovine (Cathol	religion, for example porcine (Islam, Judaism); bovine (Hinduism) products or foetal cells (Catholicism, Hinduism, Judaism).	Most of the concerns were regarding porcine content in vaccines, or their derivatives, being used to make vaccines.	, , , ,
	Appeal to natural order/ "God's will"	This theme defers to the will of a higher power, and takes several forms, such as vaccines interfere with the natural order of things or are against God's will; one should have faith instead of resorting to vaccines.	I put my trust in God. Vaccines are discursively presented by Christian activists as a biomedical claim of Divine failure; the decision to accept vaccinations implicitly means to doubt Divine intentions—which is otherwise highly transgressive for Haredi or 'God-fearing' Jews.	<i>Vaccines interfere with God's will: He will decide if people get the disease or not.</i>
	Religious advice	This theme cites advice from scripture/religious passages prohibiting vaccines, or a religious leader who advocates against vaccines. Vaccination is rejected on the basis of this advice, which is perceived to be the religious law. This theme also captures	Religious prohibitions ("infidel vaccine"). The minister of health of the Nation of Islam advised believers to avoid all immunisations	People should abide by what religious leaders say against vaccines.

Root	Theme	Explanation of theme	Arguments (examples)	Prototype argument (for persuasiveness rating)
		other instances where religion is invoked as the reason not to have a vaccine, without the specific rationale in the other themes.		
	Religious/ spiritual holism	This theme highlights the mental and physical connections with health and claims that we should not "sin" and defile the body. This may or may not include a religious component.	The introduction of unclean/unnatural materials into one's "temple" is a sin against God, as well as a slight against God's ability to design humans perfectly. Vaccines were framed as adulterating bodies, which, according to Abrahamic cosmologies, remain the property of God	The human body was created in God's image, so it is a sin to defile it with unnatural injections.
	Vaccines are discriminatory	This theme argues against the discriminatory nature of vaccines, relating it to medical malfeasance, claiming that religious exemptions must be honoured.	Racial and religious issues historically associated with malfeasance in medical research. Religious Exemption	Not allowing religious exemptions to vaccines is discriminatory.
Morality	Vaccines are unethical	This theme rejects vaccines as unethical experiments that treat people as guinea pigs, claiming that vaccine research included animal abuse or crosses ethical lines veering into enhancement, or arguing that the expanding vaccination programmes are an experiment	Sailors as guinea pigs Immoral acts: Vaccination involves immoral acts (e.g. child experimentation and animals being tortured in the process of vaccine manufacturing).	Vaccines were developed through unethical experimentation.

Root	Theme	Explanation of theme	Arguments (examples)	Prototype argument (for persuasiveness rating)
		without consent and need to be properly debated.		
	Vaccines use foetal tissues	This theme invokes moral outrage at the alleged use of foetal cells or tissues in the production of vaccines. This theme is similar to the theme of "vaccines are unethical" but recurs frequently as a particular moral issue people are worried about.	Some vaccine ingredients are derived from foetuses. Cell cultures from aborted foetal tissue are used to grow vaccine viruses.	People should not accept vaccines that are produced using tissues from aborted fetuses.
	Vaccines licence immoral behaviour	This theme occurs specifically in conjunction with the HPV vaccine, where (especially for socially conservative) individuals feel that the vaccine's protection against a sexually- transmitted disease is a licence for sexual activity at a young age, or having multiple sexual partners, which is seen as immoral.	HPV vaccine promotes sexual activity. Receipt of HPV vaccine leads to promiscuity.	Sexual abstention is preferable to taking the human papillomavirus (HPV) vaccine, which would only promote promiscuity.
	Financial profit is immoral	This theme refers to pharmaceutical profits as being inherently immoral.	Moral judgment about the health care system as profit driven	Profit-driven vaccination campaigns are immoral, promoting bad parenting and interpreting side effects as a "sacrifice".
	Other moral arguments	This theme encompasses other non-specific moral judgements, for example "bad parenting" by those who fail to challenge vaccination or "rely on vaccination" for their child's health, the anti-utilitarian stance that it is not morally right to sacrifice individuals for the sake of many, or just citing morals or	Those who relied upon vaccination for wellness demonstrated poor values: not sufficiently tending to children at home, or indeed having children for reasons that seemed unfathomable.	It's our moral duty not to rely on vaccines.

Root	Theme	Explanation of theme	Arguments (examples)	Prototype argument (for persuasiveness rating)
		tradition as grounds for vaccine rejection without further elaboration about what is moral.	Anti-utilitarian.	
Fear	Fear of side effects	This theme incorporates the fear of experiencing adverse side effects that are known to be caused by vaccines. This tends to be an aversion to minor or major but low probability side effects that are warned about–critically, those that have a basis in science (e.g. fever, sore arm, convulsions, muscle aches, weakness, fatigue, arm swelling).	Fear of adverse events is a well- documented basis for hesitancy. Minor side effects.	<i>I worry about experiencing side effects from the vaccine.</i>
	Vaccine safety	This theme captures the idea that people need to be reassured about how safe it is to have a vaccine, where safety tends to mean 100% safe and no risks. Probabilities of side effects, especially severe ones, are exaggerated, or distorted (including the perception of "hot lots" where some vaccine batches are more likely to induce to side effects. Overall, fear is induced by portraying vaccines as a safety concern.	Scepticism about vaccine safety. Vaccines should be 100% safe: Because absolute safety cannot be promised, vaccination is therefore flawed and dangerous.	Vaccines are not safe.
	Vaccine injury	This theme encompasses a number of subthemes about perceived injuries/harm/diseases and a long list of other pathological conditions caused by vaccines, including (but not limited to): autism and other developmental or behavioural defects	Firsthand testimony of parents of autistic children who are convinced of the vaccination– autism link.	Vaccines cause severe injuries and people never recover from them.

Root	Theme	Explanation of theme	Arguments (examples)	Prototype argument (for persuasiveness rating)
		or reduced intelligence (mostly MMR in children), cancer, autoimmune diseases, and infertility. Critically, the causal attribution is these cases is not scientifically evidenced. A fear of vaccine injury can sometimes be linked to conspiracist thinking, where vaccine injury is believed to be intentional and part of a sinister plot.	The Measles Mumps Rubella (MMR) vaccine in rising rates of autism.	
	Fear of toxins	This theme incorporates the fear of tainting one's body with toxic ingredients/poison/contaminants that vaccines allegedly have, including (but not limited to) additives, mercury, impurities, adjuvants, live viruses, and additional genetic material or mutated cells that will alter one's DNA.	Fears of "tainted" vaccine batches. Biological "impurities" in the vaccine; formaldehyde, glycerin, thimerosal, and aluminum.	Vaccines contaminate the human body with toxins, heavy metals or viruses that could alter DNA.
	Perceived contraindications	This theme encompasses fears of having a vaccine due to specific conditions that would be exacerbated, and often these are cases where there are no actual contraindications, for example, allergies, pregnancy, children, already had another vaccine, already sick.	Did not want to take two vaccines; as the H1N1 vaccine took preference, a barrier to the seasonal vaccine was created. Children should not receive vaccines when they are sick.	Vaccines should not be administered to vulnerable people, such as pregnant women, young children or patients with allergies.
	Immune compromise and overload	This theme relates to a fear that one's immune system will be compromised/harmed by the vaccine, including pseudoscientific theories that too many vaccines overload the immune system, or children are too young,	Babies are born with perfect immune systems; baby could be terribly injured or possibly even die.	Vaccines overwhelm the immune system, especially when taken in many doses.

Root	Theme	Explanation of theme	Arguments (examples)	Prototype argument (for persuasiveness rating)
		with underdeveloped immune systems that would be harmed.	Number and frequency of vaccine shots; Physicians wanted to give babies dozens of vaccines.	
	Needle (and procedural) phobias	This theme encompasses overwhelming fears of the procedural component of vaccination, specifically needles (e.g. trypanophobia), but also fears of pain and other processes required to vaccinate.	Pictures of "scary needles". Fear of pain.	I'm afraid of needles and fear the vaccination will hurt.
Distorted risk	Vaccine is unnecessary	This theme claims in general that the vaccine(s) (or medicine and doctors) is unnecessary, redundant, or irrelevant without further explication of why; in some cases it may be due to lack of understanding about reasons why the vaccination is needed. This theme also captures arguments that relative to other societal problems, vaccines are an unnecessary distraction/low priority.	The pertussis vaccine was seen as redundant and unnecessary. Vaccination does not seem a relevant problem to people when they have unmet basic medical and nutritional needs.	Vaccines are unnecessary and not a medical priority.
	Disease is not serious	This theme dismisses the severity of the disease, claiming that it is not dangerous, has low risk of complication, is just a minor infection, or diseases are positive for child development and the immune system. Thus, the disease is not a health concern warranting vaccination.	Did not perceive diseases such as influenza as posing a health concern to them or their patients. Smallpox was not a serious illness in any case, and that it easily treated.	Vaccine-preventable diseases are mild and can be easily treated.

Root	Theme	Explanation of theme	Arguments (examples)	Prototype argument (for persuasiveness rating)
	Low risk of infection	This theme dismisses the risk of infection/getting the disease, in extreme cases considering the disease to be non-existent or	The infection rate is practically zero in the EU.	Vaccinations are not needed if you live in a developed and safe country.
		irrelevant in their context.	Risk of cervical cancer perceived as being low.	
	Risk calculation	This theme frames the decision not to vaccinate as a calculated decision based on a risk perception that distorts the risk of disease, the risk of vaccination, and the benefits of vaccination, concluding that (inflated) disadvantages outweigh	Mainstream media overstates the risk of communicable diseases to promote vaccination, as well as instills a sense of fear of the disease.	Vaccines are riskier than the diseases themselves.
	(diminished) benefits of vaccines. Arguments also claim that their distorted perceptions are true and <i>others</i> are distorting the risks.	Perceive vaccinations as being riskier than the diseases themselves (mumps and chicken pox).		
	Appeal to immunity	This theme also dismisses the risk of the disease, but specifically links it either to one's own immunity, whether through lifestyle choices, religious protection, or personal good health, or the belief that the disease will confer beneficial natural immunity.	Muslims are immune to the virus. Believe that their immune system is capable of managing trivial disease.	Vaccination is unnecessary if you have a strong immune system that protects you from vaccine- preventable diseases.
Selfishness	Freeriding	This theme shows an understanding of the risks of not vaccinating, but individuals do not want to subject themselves/their child to risk of vaccination so prefer others take that on instead. It talks about prioritising their child, putting their child first, doing their duty to their child instead of the community, and	A child should not be vaccinated with the aim of protecting others. Overwhelmingly put protecting their child over protecting society's children.	People should look after their own health rather than put themselves or their child at risk to protect others.

Root	Theme	Explanation of theme	Arguments (examples)	Prototype argument (for persuasiveness rating)
		rejects the idea that one should be vaccinated to protect others.		
	Controlling others' behaviour	This theme reflects a belief that other people should just behave better (e.g. quarantine, social distance): why should one have to be vaccinated because others are not behaving well?	Those individuals should not rely on others to get vaccinated but should instead take all necessary precautions such as wearing facemasks, avoiding areas where infections are more rampant, and hygienic measures. Social responsibility is	We should not be forced to take vaccines because other people do not take protective measures to stop spreading the disease.
			quarantine.	
	Herd immunity already exists	This theme questions the need for vaccination due to a belief that others have already achieved herd immunity, so they/their child does not need to be put at risk.	Why should I expose my child to a vaccine risk, when the infection rate is practically zero in the EU?	People do not need to be vaccinated as long as herd immunity exists.
			Herd immunity works so vaccination is not necessary.	
Epistemic relativism	Anti-science position: truth is relative	This theme draws on strands of postmodernist thought, for example, by rejecting scientific or objective epistemology and expertise, claiming that it is all "relative". Arguments in this theme may dismiss scientific medicine as "conventional", "outdated", "uncritical", merely a "social construction", a political agenda, or a means of colonial oppression.	Outdated, elitist, conception of science. Truth itself is a relative entity.	The "theories" on which vaccines are based are not "objective" or "true" but are a social construction by scientists that is being imposed on other equally valid perspectives.

Root	Theme	Explanation of theme	Arguments (examples)	Prototype argument (for persuasiveness rating)
		The conclusion is typically that science and medicine are wrong or inferior.		
	Anecdotes trump scienceThis theme privileges anecdotes and personal experiences over scientific evidence, referring to first-hand "testimony" and personal narratives as "evidence" that vaccines are injurious and harmful.Parents who had experienced what they believed to be vaccine damage to their children.Victims-compelling personal testimony that anthrax vaccine causes serious side effects.	Parents who had experienced what they believed to be vaccine damage to their children.	Negative experiences and testimonies of injuries by patients should be prioritized when deciding whether or not to	
		injurious and harmful.	Victims—compelling personal testimony that anthrax vaccine causes serious side effects.	accept vaccination.
	Privileging unwarranted beliefs	This theme places the individual's unwarranted belief (e.g. in CAM, their own traditions) or alternate viewpoints on equal footing with scientific evidence in guiding a vaccination decision.	Uniform vaccination programs might not be justified because they fail to meaningfully take into account CAM perspectives, evidence from clinical experiences, and individual patients' contexts and wishes. An anti-medicalisation movement that led some to question the new push for vaccination against infections.	There are alternative perspectives on health that are more comprehensive and holistic and that the vaccination movement is not respecting.
	Individual experts: "did my own research"	This theme draws strongly on the argument that the individual is the expert for themselves, and so their knowledge takes precedence over medical/scientific experts. It often invokes the idea of maternal empowerment, claiming that "mother knows best", and people should rely on their instincts	Parents know their children best; parents are experts on children. Rejected the idea that medical expertise, especially clinical data tabulated by practitioners in-	People are experts of their own bodies and when they read up on their health, they may legitimately conclude that vaccination is not for them.

Root	Theme	Explanation of theme	Arguments (examples)	Prototype argument (for persuasiveness rating)
		and gut feeling and not doctors. This theme also highlights individuals having done or doing their own research that is superior to experts or includes information experts don't know about.	the-field, should be unquestionably privileged.	
	Impossible expectations of science	This theme displays fallacies like "all or nothing thinking" (e.g. vaccine is ineffective if it fails just once) and demanding "objective scrutiny", misunderstanding how science works, believing it is uncritical, or cherry- picking results, citing experts who depart from the established science – basically claiming these are good evidence or ways to attain good evidence.	Allegedly reliable information about immunisation that ran counter to generally accepted wisdom about the benefits, safety and efficacy of vaccines. Included here were accounts of 'experts' who disagreed with the orthodoxy on vaccines. Generalises from a single case (of vaccine failure) to suggesting the entire program is a failure.	The vaccine does not work for everyone, and we should not take risks with anything that is less than 100% effective.
Reactance	Resisting threats or coercion	This theme refers to a pushback against an authority who threatens or coerces people to be vaccinated, often citing punishment, retribution, use of force, or harassment/bullying as reasons to be against vaccination.	Vaccine programs harass parents who do not vaccinate. Punitive actions are further stoking hatred against polio vaccination.	Vaccination campaigns bully and harass people into getting a vaccine.
	Personal autonomy	This theme sets out vaccination as a personal decision that should be left up to the individual, often invoking the term "choice" or "autonomy", and claiming that people can make responsible, informed decisions to	The decision about whether to vaccinate was a personal one and that they could make up their own minds about what was best for their child.	People should be able to decide what goes into their bodies, and therefore it should be a matter of free personal choice whether someone gets a vaccine.

Root	Theme	Explanation of theme	Arguments (examples)	Prototype argument (for persuasiveness rating)
		refuse a vaccine. This is also often seen as a sense of empowerment and bodily control/governance.	Refusal of vaccination is an informed and responsible decision.	
	Violation of rights and freedom	This theme claims that vaccination is a human right and/or civil liberties issue, and requiring/recommending vaccination violates one's rights as a person/citizen to decide what goes into one's body. The arguments often fight back against perceived authoritarian or totalitarian state overreach or abuse of power, in some extreme cases labelling it "slavery", "tyranny".	Common rights are being stripped from you! They articulated that their 'right' to contract a disease and life- long immunity had been taken away by an over-interventionist state.	We need to resist an authoritarian state that is abusing its power and violating individual rights by telling us to get vaccinated.
	Non-conformity	This theme emphasises the need to behave contrary to expectations, reject the "herd" mentality and the perception that one is just a "statistic", claiming that vaccines are not "one size fits all". Underlying these arguments is a perception that those who get vaccinated without question are ignorant, uncritical, or otherwise deficient, and that medical/government authorities are paternalistic and censor disagreements.	Ignorant, uncritical or fearful conformity. Herd immunity implies herd mentality.	People are getting vaccinated out of ignorance and fear, according to what the nanny state expects of them.

Study 2: Case study on COVID-19 anti-vaccination misinformation

To assess the applicability of the attitude roots in our taxonomy to presently circulating anti-vaccine misinformation, we focused on COVID-19 vaccines as a case study. COVID-19 vaccinations have perhaps the widest reach and greatest prominence of all vaccines currently, with most countries worldwide carrying out large-scale vaccination programmes that target almost all age groups. Anti-vaccination messages, in particular because of their reliance on misinformation, hinder the objectives of these programmes. If addressing the roots of anti-vaccination attitudes is critical to combating vaccine hesitancy (as proposed by Hornsey & Fielding, 2017), it is necessary to assess the applicability of our taxonomy to the COVID-19 case. Moreover, given the paucity of existing research on COVID-19 vaccine misinformation, and given the reliance on the academic literature in our first study, we used a different source of data in this study.

Sample

We used the <u>https://covid19misinfo.org</u> portal to search for vaccine-related misinformation. The portal is a rapid response project that has tracked debunked coronavirus claims circulating online since the start of the pandemic. These claims were sourced and debunked by hundreds of trusted fact-checkers from around the world (Gruzd & Mai, 2020), making the portal a good source for misinforming messages that had gained sufficient traction during the pandemic to attract the attention of fact checkers. Because the portal did not offer a way to specifically search for anti-vaccination claims, we focused our search on all vaccine-related claims, using the search terms "vacc" and "vax" separately to capture these items. The search was performed on 6 August 2021, which included items from 23 January 2020 up to that date.

We excluded arguments that had been fact-checked to be true, arguments that did not relate to antivaccination, and duplicated arguments – considering as duplicates two arguments with the same wording, two similar arguments coming from the same fact check or two arguments extracted from the same source (e.g. a tweet or Facebook post). This resulted in a dataset of 623 false anti-vaccination claims that had been debunked by fact checkers. Each claim consisted of a link to the full text and a headline summarizing the claim. Headlines were between 4 and 88 words in length (mean 15.2, median 13). Two researchers then independently identified the attitude roots for each of these headlines. As in Study 1, disagreements in coding were resolved by discussion.

Descriptive analysis of claims

All roots except epistemic relativism were present in the data, although only one instance of selfishness was identified, representing < 1% of the claims. Figure 8 shows the distribution of roots together with the distribution from Study 1. The top three most frequent roots were similar to those identified in the literature review: fears and phobias (32.8%), distrust (22.4%), and unwarranted beliefs (17.1%). The overlap between the two distributions is quite striking, which is reassuring because it suggests that (at least at a coarse quantitative level), the scholarly literature yields the same pattern of classifications as our own analysis of the contemporary case of COVID-19 misinformation. We next employed confirmatory topic modelling to seek further quantitative validation of our taxonomy.



Figure 8: Comparison between attitude root frequencies among academic articles (in blue; see also Figure 4) and fact checks (in red).

Confirmatory topic modelling

Overview

The purpose of the topic modelling was to relate the two studies to each other and to provide quantitative support for our taxonomy. Figure 9 provides an overview of the approach. In both studies, our analysis assigned attitude roots to arguments (Study 1, left-hand side of the figure) and debunked misinformation (Study 2, right). This assignment required human judgement in both cases, as discussed and as indicated in the figure. For Study 1, we also reported word clouds for each root across all relevant arguments (Figures 5 through 7) which were found to capture the essence of the roots.

For the confirmatory text modelling of material from Study 2, we made use of those word clouds to "seed" the topic modelling of the full text (rather than just headlines) of all 623 fact checks of the debunked COVID-19 claims. The intention of the topic modelling was to (1) identify the 11 roots as distinct topics in the fact-check corpus, and (2) to use those models to predict the root assignment for each item in the fact-check corpus. If the text modelling captures the deep psychological structure in the debunked claims, then the text model should predict the assigned root for each claim with above-chance accuracy (see red arrow in Figure 9).



Figure 9: Overview of confirmatory text modelling. See text for details.

Latent Dirichlet Allocation topic modelling

We chose to use Latent Dirichlet Allocation (LDA; Blei, 2012; Blei, Ng, & Jordan, 2003) to represent the topics in our fact-check corpus. LDA is based on the intuition that a set of documents typically exhibits multiple topics, and that each word's presence in a document is attributable to one of those topics. When LDA is applied to a set of documents, it identifies a specified number of topics, and generates a parametric model of clusters of co-occurring words and their relationship to documents and topics. Once estimated, the model can be interrogated to establish the principal topic of any given document, and the most likely words associated with each topic across documents. The contribution of a topic to each document is captured by the parameter γ , and the likelihood that a given word appears in a topic is represented by the parameter β . In standard LDA, the modelling is unsupervised and the only input provided by the researcher (other than a corpus of text) is the number of to-be-identified topics. The nature of those topics remains entirely unconstrained and is revealed by the LDA.

Here, we use a variant of LDA known as "seeded LDA" (Curini & Vignoli, 2021; Watanabe & Zhou, 2020), in which the researcher additionally provides a list of seed words for each prespecified topic. This constrains the topic model without, however, predetermining the outcome exactly. One major advantage of seeded LDA is that the nature of the topics does not have to be inferred by examining the list of associated words but is constrained ahead of time by knowledge of the seed words. We used the LDA function in the R package topic models.

We obtained seed words in a similar manner to the word clouds, by rank ordering words within each argument (using the specific level in the argument corpus from Study 1) according to their frequency, and selecting the top 8 words as seeds for the LDA. The 8 seed words for each topic were given the weights 700, 650, 350 for the LDA in decreasing order of frequency. Weights were chosen to ensure a relatively homogeneous distribution of β across the top 20 words within each of the extracted topics, and a blending of seed words and other items from the text among the top 20 words.

Results of seeded LDA

Table 2 shows the seed words for each root, and Figure 10 shows the top 20 words (i.e. largest values of β) for each topic identified by the seeded LDA in the fact-check corpus. The figure shows that each of the seeded topics is meaningfully identified in the text. In particular, each topic is not just defined by the seeds but involves words from the corpus whose value of β is equal to, or exceeds, the value of the seed words. This confirms that the text model was only partially supervised and that the seeds did not override the statistical structure in the text.

Root	Seed words
Conspiracist ideation	conspiracy; government; big; pharma; pharmaceutical; people; companies; control
Distrust	health; doctors; pharmaceutical; information; government; lack; medical; companies
Unwarranted beliefs	immunity; natural; diseases; disease; health; children; immune; system
Worldview/politics	government; health; authorities; political; injury; power; social; anti
Religiosity/Spirituality	religious; god; cells; health; beliefs; aborted; body
Morality concerns	sexual; acts; children; aborted; immoral; religious; activity; anti
Fear and phobias	autism; children; effects; side; immune; disease; death; diseases
Distorted risk perception	disease; diseases; risk; immunity; influenza; perceived risks; measles
Selfishness	herd; risks; child; health; immunity; patients; protecting
Epistemic relativism	children; mothers; parents; medical; health; knowledge; personal; research
Reactance	parents; choice; freedom; children; health; parental; civil; government

Table 2: Seed words used in confirmatory LDA for the 11 root topics



Figure 10: Top 20 words for each topic (root) identified by the seeded LDA. See text for details.

Validation of confirmatory text modelling

The final step was to validate the seeded LDA model of the fact check text. For each entry in the fact check corpus we identified the predominant topic, defined as the topic with the largest value of γ . We refer to this topic as the predicted root, and we compared the predicted roots to the roots that were assigned by human coders to each headline claim in Study 2. When the predicted root and assigned root are identical, prediction has been successful. On the basis of chance alone, this would occur on 9.09% (1/11) of all cases. We found that the model predicted the assigned root correctly on 16.7% of all cases, a value that was 6.46 standard deviations above the performance expected on the basis of chance alone.

Because some of the roots are arguably closely related to each other, which would make discrimination unduly difficult, we performed another validation in which 4 pairs of roots were collapsed into a single root each: the pairs were (1) conspiratorial ideation and distrust, (2) religiosity and moral concerns, (3) fear and distorted risk perception, and (4) selfishness and reactance. This coarse coding raised accuracy of prediction to 25.6% (chance performance 14.3%, 1/7). This accuracy value was 7.8 standard deviations above the chance performance.

Although a 7% or 11% increase in accuracy may appear modest in absolute terms, it must be borne in mind that the model extracted this signal under quite challenging circumstances: first, the assignment of topics to headline claims was made by human judges who did not have access to the full text of the fact check. Second, the topic models were seeded with text that was based on an entirely different source, namely the scientific literature pertaining to all anti-vaccination rhetoric over an extended time period (most of it predating the pandemic), rather than fact-checked misinformation about a specific vaccine during a pandemic. We therefore suggest that the information in our taxonomy derived from Study 1 provides discernible information for computational analysis of debunked anti-vaccination claims relating to COVID-19.

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