Review

A systematic review of communication interventions for countering vaccine misinformation

Hannah S. Whitehead [a], Clare E. French [b], Deborah M. Caldwell [b], Louise Letley [c], Sandra Mounier-Jack [a,*]

[a] NIHR Health Protection Research Unit in Vaccines and Immunisation, Department of Global Health Development, Faculty of Public Health and Policy, London School of Hygiene and Tropical Medicine, United Kingdom
[b] NIHR Health Protection Research Unit in Behavioural Science and Evaluation, Population Health Sciences, Bristol Medical School, University of Bristol, Bristol, United Kingdom
[c] UK Health Security Agency (UKHSA), United Kingdom

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ABSTRACT

Background: Misinformation and disinformation around vaccines has grown in recent years, exacerbated during the Covid-19 pandemic. Effective strategies for countering vaccine misinformation and disinformation are crucial for tackling vaccine hesitancy. We conducted a systematic review to identify and describe communications-based strategies used to prevent and ameliorate the effect of mis- and disinformation on people's attitudes and behaviours surrounding vaccination (objective 1) and examined their effectiveness (objective 2).

Methods: We searched CINAHL, Web of Science, Scopus, MEDLINE, Embase, PsycInfo and MedRxiv in March 2021. The search strategy was built around three themes(1) communications and media; (2) misinformation; and (3) vaccines. For trials addressing objective 2, risk of bias was assessed using the Cochrane risk of bias in randomized trials tool (RoB2).

Results: Of 2000 identified records, 34 eligible studies addressed objective 1, 29 of which also addressed objective 2 (25 RCTs and 4 before-and-after studies). Nine 'intervention approaches' were identified; most focused on content of the intervention or message (debunking/correctional, informational, use of disease images or other 'scare tactics', use of humour, message intensity, inclusion of misinformation warnings, and communicating weight of evidence), while two focused on delivery of the intervention or message (timing and source). Some strategies, such as scare tactics, appear to be ineffective and may increase misinformation endorsement. Communicating with certainty, rather than acknowledging uncertainty around vaccine efficacy or risks, was also found to backfire. Promising approaches include communicating the weight-of-evidence and scientific consensus around vaccines and related myths, using humour and incorporating warnings about encountering misinformation. Trying to debunk misinformation, informational approaches, and communicating uncertainty had mixed results.

Conclusion: This review identifies some promising communication strategies for addressing vaccine misinformation. Interventions should be further evaluated by measuring effects on vaccine uptake, rather than distal outcomes such as knowledge and attitudes, in quasi-experimental and real-life contexts.

Contents

* Corresponding author at: London School of Hygiene and Tropical Medicine, Keppel St, London WC1E 7HT, United Kingdom.
  E-mail address: Sandra.Mounier-Jack@lshtm.ac.uk (S. Mounier-Jack).

1. Introduction

The COVID-19 pandemic has highlighted the ongoing public health challenge of vaccine hesitancy and vaccine refusal, and the misinformation, disinformation, and myths that feed into them. Even prior to the current pandemic, the World Health Organization (WHO) identified vaccine hesitancy - defined as the delay in acceptance or refusal of vaccines, despite their availability [1] - as a top global health threat [2]. While vaccine controversies in recent years have underscored this threat, the COVID-19 pandemic has thrown a spotlight onto it.

Hesitancy is context dependent and varies greatly both within and between countries as exemplified by the COVID-19 vaccination [3]. Several models explain the varied components and antecedents of vaccine hesitancy, including the '3C' model (confidence, complacency, and convenience) which has been expanded upon by the more recent '5C' and '7C' models (confidence, complacency, constraints, calculation, collective responsibility, and conspiracy), and the '5A' taxonomy of vaccination determinants (access, affordability, awareness, acceptance, and activation [1,4–6].More complex and context-specific frameworks have also been developed to conceptualize the factors influencing vaccine hesitancy and uptake, such as the Adapted Royal Society of Canada Vaccine Uptake Framework and the SAGE Working Group's Vaccine Hesitancy Determinants Matrix, which underscores the complexity and multitude of factors that can contribute to vaccine hesitancy, including the communication and media environment, knowledge/awareness, and the attitudes and experiences of family and health professionals [1,7]. Misinformation intersects with many potential determinants and can undermine vaccine confidence, defined in the 3C's model as "trust in (i) the effectiveness and safety of vaccines; (ii) the system that delivers them, including the reliability and competence of the health services and health professionals and (iii) the motivations of policy-makers who decide on the needed vaccines" [1].There has been an increase in health-related mis- and dis-information in recent years, with vaccines and infectious diseases a major focus [8]. Misinformation is inaccurate information that is unintentionally presented as fact, while disinformation involves deliberately spreading false information to cause harm. In the current era of 'fake news' and ubiquitous use of the internet and social media, increasing circulation of and exposure to mis- and dis-information has been linked to higher levels of persistent vaccine hesitancy despite some social media platform algorithms attempting to minimize biases and the spread of mis and dis-information [9–13].

Developing and tailoring effective health communications and campaigns to counter vaccine misinformation is essential, both for maximizing vaccine uptake as the COVID-19 pandemic continues and for ensuring high uptake of other existing and future vaccines to prevent and control disease outbreaks. Understanding the various strategies that have been tested or used to counter vaccine misinformation and disinformation and identifying those that are potentially effective (as well as those that work less well or backfire) is crucial in order to tackle vaccine hesitancy. Previous systematic reviews [14–19] have examined interventions for addressing vaccine hesitancy and correcting misinformation of various health topics, but to our knowledge, no review has specifically examined communication-based strategies for countering vaccine misinformation.

1.1. The objectives of this systematic review are to:

1) identify and describe communication-based strategies that have been used to prevent or ameliorate the impact of vaccine misinformation and disinformation on people's attitudes and behaviors surrounding vaccination.
2) identify strategies which appear to be effective in countering vaccine mis- and disinformation.

The study was registered with PROSPERO (CRD42021243341) and is reported in accordance with PRISMA guidance [20]. Changes from protocol are briefly noted in the text.

2. Materials and methods

2.1. Search strategy

We searched CINAHL, Web of Science, Scopus, MEDLINE, Embase and PsycInfo databases using a search strategy developed in consultation with an information specialist (see Appendix A for search strategy used in MEDLINE). Search strategies from previously published reviews on related subjects [21,22] were used as a reference to develop comprehensive lists of search terms, which were grouped around three themes: (1) communications and media, (2) misinformation, disinformation, myths, etc, and (3) vaccines. Searches were conducted in March 2021 with no limits on publication date. To capture current research on the COVID-19 pandemic, we also searched MedRxiv, a non-commercial pre-print online repository, using truncated sets of the search terms in Appendix A.

2.2. Study eligibility and selection

Citations were imported into a Rayyan online library[23]. Studies were screened for eligibility based on inclusion and exclusion criteria described in Box 1. Title and abstract screening was conducted by two reviewers independently, with disagreements resolved by a third reviewer. Articles selected for full text screen-

ing were exported to an EndNote library. One reviewer conducted full text screening, with uncertainties resolved by a second reviewer.

Data availability

No data was used for the research described in the article.

2.3. Data extraction

Data were extracted by one reviewer using a pre-defined Excel database. Data extracted included publication descriptors, disease or vaccine of focus, study design, sample characteristics, comparator group information, description of the intervention, whether intervention effectiveness was assessed, and key results, including which, if any, outcomes were reported. Relevant outcomes were any author-defined measure of attitudes towards vaccines or vaccine-related information (including vaccine hesitancy), accurate knowledge of vaccines, belief in misinformation, and intention to vaccinate.

2.4. Data synthesis

For objective 1, the primary approach to data synthesis was grouping interventions by type or format (i.e., pamphlet, social media-based intervention, informational text) and content or communication strategy/approach (i.e., informational, myths vs facts approach, use of humor and logic) and summarizing intervention design by group. Groupings were developed inductively, following data extraction, and refined throughout synthesis.

For objective 2, study outcomes were iteratively grouped and ultimately classified into (1) belief in or endorsement of mis- or disinformation, (2) knowledge about vaccines and related diseases, (3) attitudes and beliefs about vaccination, including measures of vaccine hesitancy, and (4) intention to vaccinate. Data from comparative studies was summarized in tabular form, stratified by intervention strategy/approach and outcomes to develop an effect direction plot [25]. meta-analysis was considered inappropriate due to wide variation in both the type/format of interventions and content or communication strategy/approach.

For brevity throughout this review, we use the term 'misinformation' as an umbrella term to refer to false information, myths, and misperceptions, as the focus of the included studies and this review is on interventions rather than assessing the source and intent of false information.

2.5. Risk of bias

The RoB 2 tool [26] was employed to assess randomized controlled trials (RCTs) (n = 25), and one cluster-randomized trial was assessed using the RoB 2 tool for cluster-randomized trials [27]. Two reviewers independently assessed each study. Disagreements were discussed and resolved accordingly. The *robvis* web application [28] was used to generate a summary risk-of-bias plot.

3. Results

After deduplication, 1800 unique results were returned from the database searches. An additional 200 articles from MedRxiv were screened from which 6 further articles were identified. A total of 142 articles were selected for full-text screening (Fig. 1).

In total, 34 studies, including four preprints, were eligible for inclusion. Study characteristics are described in Table 1. These included 25 RCTs (including one cluster-randomized trial and

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Box 1 Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Objective 1 & 2 - Publications that describe or assess communication-based strategies, programs, or interventions that explicitly aim to address misinformation, disinformation, or myths about vaccines, either preventatively or reactively- Research/ interventions conducted in high-income countries, defined per World Bank classification [24]- Study type: single-arm studies without a control group (objective 1 only); comparative studies (experimental or observational) (objectives 1 and 2).	- Literature reviews and systematic reviews- Commentaries, letter to editor, and similar publication types that do not describe or assess a relevant communications intervention aimed at addressing vaccine misinformation, disinformation, or myths- Conference abstracts- Interventions targeted at health professionals or trainees, rather than intended for the general population- non-English language publications
Objective 2 only - Studies that utilized a comparative or pre/post design - Studies that reported quantitative outcomes related to attitudes towards vaccines or vaccine-related information, accurate knowledge of vaccines, vaccine hesitancy or vaccine confidence	- Studies reporting no outcome measures - Narrative descriptions of interventions

Identification of studies via databases and registers

Identification

Records identified from:
Databases (n = 4842)
Registers (n = 200)

→

Records removed *before screening*:
Duplicate records removed
(n = 3042)

Screening

Records screened
(n = 1800 from databases
n=200 from medRxiv)

→

Records excluded
(n = 1664 from databases
n = 194 from medRxiv)

Reports sought for retrieval
(n = 142)

→

Reports not retrieved (full text not located)
(n = 7)

Reports assessed for eligibility
(n = 135)

→

Reports excluded:
No intervention (n = 32)
Not misinformation-specific (n = 22)
Wrong publication type (n = 38)
Wrong population/country (n=6)
Not vaccine specific (n = 2)
Wrong language (n=1)

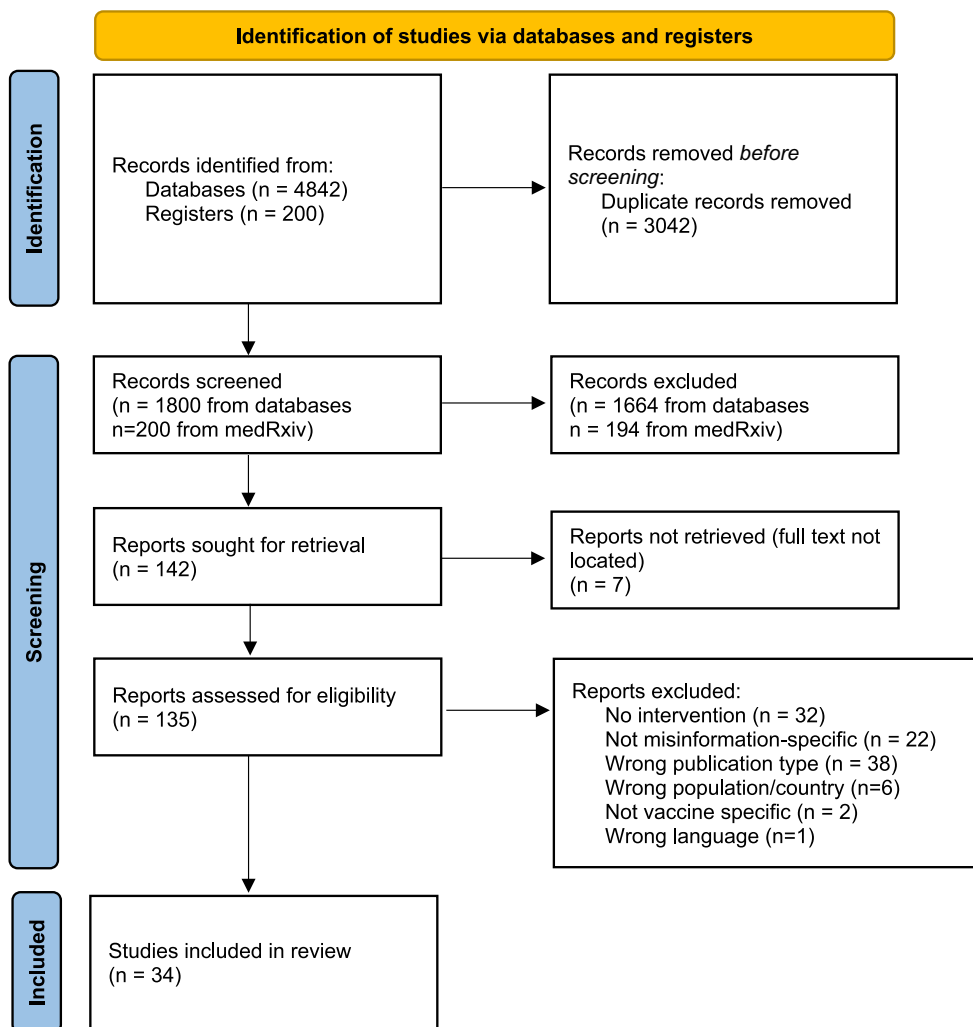**Included**

Studies included in review
(n = 34)

Fig. 1. PRISMA 2020 flow diagram [20].

one quasi-randomized trial), six single-arm studies, two narrative descriptions of interventions or intervention development, and one website content analysis. Most were conducted in the United States (n = 21), followed by the United Kingdom (n = 6), and Italy (n = 2). The remaining studies were conducted in Germany, France, Canada, Israel, and Singapore (1 study each). Three studies included respondents from multiple countries. One study did not specify location [29].

All but two studies were published within the past decade. 23 studies addressed specific vaccines and/or diseases (most commonly measles, mumps and rubella (MMR) and influenza), while nine studies considered vaccines generally and two utilized fictitious diseases and vaccines.

Primary outcomes of interest reported on included vaccine-related beliefs, knowledge, and attitudes, and specifically, intention to vaccinate (though this was often assessed as a hypothetical intention). None of the articles measured vaccine uptake or coverage.

3.1. Objective 1 – Description of interventions

The interventions presented in the 34 included studies ranged widely, both in form and in messaging strategies. We outlined both the format and content and messaging approaches below while the format of intervention is described in more details in able. Study characteristics are summarized in Table 1, with additional detail

on sample characteristics in Appendix Table A1, and the distribution of intervention strategies and approaches is displayed in Table 2.

3.2. Intervention format

A variety of intervention formats and mediums were represented and described in detail in Table 3. They encompassed question-and-answer style pamphlets about childhood vaccines [30], mock news articles [29,31–33], government announcements [34], debunking messages posted on social media [35–38], and complex interactive strategies delivered both in-person [39,40] and online [41].

3.3. Thematic analysis of communication strategies

While the included interventions varied widely in their form, thematic similarities in approach and content emerged. These approaches or strategies emerged as intervention characteristics were extracted, and inductively grouped and re-grouped. Table 2 displays the heterogeneity in interventions and communication strategies' form and approach. Nine 'intervention approaches' were identified; most focused on the **content** of the intervention or message (debunking/correctional, informational, use of disease images or other 'scare tactics', use of humor, message intensity, inclusion of misinformation warnings, and communicating weight of evi-

Table 1
Characteristics of included studies.

Author (*preprint)	Year	Vaccine	Country	Study Design	Description of Intervention	Sample Size	Risk of Bias	Print	Video/Multi-media	In-person inter-active	Social media	Web-based	News articles	Visuals	Msg. manip-ulations	Debunking/ Correctional	Informational	Disease images & scare tactics	Msg. timing	Msg. source	Humor	Msg. intensity	Misinfo. warning	Weight of Evidence
Batteux et al*	2021	COVID-19	UK	RCT	Messages communicating vaccine effectiveness with varying levels of certainty	328	Some								X							X		
Betsch & Sachse	2013	Fictional	Germany	RCT	Simulated websites with differing number, strength, and source credibility of myth negation messages	115/119	High					X										X		
Bode & Vraga	2015	autism-vaccine link	US	RCT with pre/post	Facebook related news links with articles confirming or refuting misperception	524	Some				X					X								
Boyle et al	2014	HPV	US	pre/post	Spanish-English bilingual fotonovela	22	NA	X						X			X							
Brueggmann et al	2016	HPV	US	post-test only	Educational pamphlet	418	NA	X									X							
Dixon et al	2015	autism-vaccine link	US	RCT	Weight of evidence messages with visual exemplars	371	Some						X	X										X
Evers	2001	childhood vaccines	US	pre/post	Q&A educational pamphlet	10	NA	X									X							
Featherstone & Zhang	2020	Measles/MMR	US	RCT with pre/post	Refutational messages using conspiracy and uncertainty framing 2018	609	High								X	X								
Gesser-Edelsburg et al	2018			FGDs + pre/post survey	243 messages	Some									X	Measles/MMR X; Israel		RCT						
Ho et al	2017	influenza & pneumococcal	Singapore	Group educational sessions	604	NA									X		X							
Jolley & Douglas	2017	General	US	RCT	Articles with anti-conspiracy arguments	267/180	Some						X						X					
Kerr et al*	2021	COVID-19	UK	RCT	Information presented with factbox, Q&A format, vaccine approval message, or vaccine mechanism message; varying length and certainty in messages about vaccine efficacy	2,097/2,217	Some								X		X					X		
Kim et al	2020	HPV	US	RCT	Humor-based and logic-based correction messages	61	Some				X					X	X							
Knight et al*	2021	COVID-19	UK	Narrative description	Web-based therapeutic dialogues	n/a	NA		X			X				X	X				X			
Kortum et al	2008	General	US	pre/post survey	Fact-based vaccine video	34	NA		X								X							
Ludolph et al	2016	General	multiple	RCT	Manipulation of Google knowledge box	279	Some					X					X						X	
Marcus	2020	Measles/MMR	US	Narrative description	Community-based nursing program	n/a	NA	X		X						X	X						X	
Moyer-Gusé et al	2018	Measles/MMR	US	RCT with pre/post	Humorous and non-humorous messages	187	Some								X						X			
Nyhan & Reifler	2015	influenza	US	RCT	Correction and danger messages	1000	Some								X	X	X							
Nyhan et al	2014	Measles/MMR	US	RCT	Debunking message; disease dangers message; disease images; dramatic narrative	1759	Some							X	X	X	X	X						
Pluviano et al	2020	Fictional	Scotland	Quasi-randomized experiment	Corrective messages from sources of varying expertise and trustworthiness	90	High						X		X	X				X				
Pluviano et al	2017	General	Scotland & Italy	RCT with pre/post	Myths vs Facts booklet; visual correction with infographics; fear correction with photos	134	Some	X						X		X	X	X						
Pluviano et al	2019	General	Italy	Cluster-randomized RCT with pre/post	Myths vs Facts booklet	60	Some	X								X								
Ryan et al	2020	whooping cough	England	RCT	Disease risk message and myth busting message	282	Some							X	X	X	X							
Stojanov	2015	General	not reported	RCT	Article with debunking message and with debunking message + information about conspiracists' motivation and fallacy in their thinking	160	Some						X		X	X								
Sullivan	2019	influenza	US	RCT with pre/post	Refutational messages from different sources	625	Some				X									X				
Trujillo et al	2020	Measles/MMR	US	RCT with pre/post	Articles targeting psychological traits of need for cognitive closure, moral purity, and needle sensitivity	7,019	High				X		X			X	X	X						
Tully et al	2020	influenza	US	RCT	News literacy message on how to spot fake news	1,214	Some							X									X	
van der Linden et al	2015	autism-vaccine link	US	RCT	Messages highlighting medical consensus for vaccine safety or support for mandatory vaccination	206	Some																X	X
Vaughn & Johnson	2018	influenza	US	RCT with pre/post	Refutational text addressing myths; expository text with factual information	64	Some								X	X	X							
Vivion et al	2020	General	France & Canada	Content analysis	Health authorities' websites	n/a	NA					X				X	X							
Vraga et al	2019	HPV	US	RCT with pre/post	Humor-based and logic-based correction messages	406	Some				X										X			
Witus & Larson*	2021	COVID-19	US	RCT	Educational video	1,632	High		X						X		X							
Zangger Eby	2017	General	US	Non-randomized intervention; pretest only	Voice-over PowerPoint presentation	23	NA		X								X							

Table 2
Format and intervention approach of communications interventions/strategies for countering vaccine misinformation.

		Intervention Approach								
		Debunking	Informational	Disease images & scare tactics	Message timing	Message Source	Humor	Message Intensity	Mis-information warning	Weight of Evidence
Format of Intervention/ Strategy	**Print**	Pluviano 2019 Pluviano 2017	Boyte 2014 Brueggmann 2016 Evers 2001 Marcus 2020 Kortum 2008 Witus & Larson 2021 Zangger Eby 2017							
	Video/ Multimedia									
	In-person interactive	Marcus 2020	Ho 2017 Marcus 2020			Witus & Larson 2021			Marcus 2020	
	Social media	Bode & Vraga 2015 Gesser-Edelsburg 2018 Sullivan 2019				Sullivan 2019	Kim 2020 Vraga 2019		Tully 2020	
	Web-based	Vivion 2020	Knight 2021 Vivion 2020			Betsch & Sasche 2013		Betsch & Sasche 2013	Ludolph 2016	
	News articles	Stojanov 2015 Trujillo 2020	Trujillo 2020	Trujillo 2020	Jolley & Douglas 2017					Dixon 2015
	Visuals		Boyte 2014 Pluviano 2017	Nyhan 2014 Pluviano 2017						Dixon 2015 van der Linden 2015
	Message manipulations	Featherstone & Zhang 2020 Nyhan & Reifler 2015 Ryan 2020 Vaughn & Johnson 2018 Nyhan 2014	Kerr 2021 Nyhan & Reifler 2015 Ryan 2020 Nyhan 2014	Nyhan 2014		Pluviano 2020	Moyer-Guse 2018	Batteux et al 2021 Kerr 2021		
Effect	**Summary of Approach's Effect (See Table 4 for details)**	Mostly mixed/no clear effect	Mostly mixed or positive effect	Mostly mixed or negative effect	Positive effect for corrective message prior to misinformation exposure	Mostly mixed/ no clear effect	Positive effect	Mostly mixed/no clear effect; some positive effect of less intense messages	Simple warnings: mostly mixed or positive effect	Mostly positive effect

dence), while two focused on the **delivery** of the intervention or message (message timing and message source).

3.3.1. Debunking, correction, and refutational approaches

Many studies utilized or assessed different types of refutational or debunking messages or approaches, in which misinformation or myths were addressed head on and corrected. This was done in various forms, including pamphlets and websites that laid out common vaccine myths and corresponding corrective facts [42–44], while other studies tested the effects of refutational texts as compared to expository, informational texts [45] or compared responding to misinformation on social media with different types or sources of debunking or refutational messages [35,37]. A community nursing program aiming to address measles vaccine hesitancy [40] included aspects of misinformation debunking and refutation, including developing a pamphlet directly countering a disinformation pamphlet that had circulated in the community. Bode & Vraga [46] tested the use of Facebook's 'related news' function to respond to posts containing misinformation by showing related articles that either confirmed or refuted misinformation about the vaccine-autism link. Trujillo et al's study [33] assessed the impact of articles that utilized 'psychographic microtargeting' to address misinformation about the MMR vaccine.

3.3.2. Informational approaches

While several included interventions or communication approaches focused on refuting or correcting misinformation, another large group examined communication strategies that took a more informational or educational approach, focused on providing information on vaccines and vaccine-preventable diseases in a factual manner (rather than directly addressing or debunking myths and misperceptions), though this was done through both direct (i.e. listing facts) and less direct approaches (such as conveying information through a story). The informational/educational interventions, which were often informed by or aiming to address misinformation, included a *fotonovela* [47], pamphlets [30,48], informational government-run websites [44], videos [49,50], PowerPoint presentations for new parents [51], manipulating search engines to provide information on vaccines [52], community-based educational programs [39,40], virtual, interactive dialogues that provide information addressing key vaccine concerns in an empathetic way intended to foster behavior change [41], and different types of informational messages, which range from providing information on the risks of vaccine-preventable diseases [53–55] or explaining how vaccines work or are approved [56].

3.3.3. Use of disease images & other 'scare tactics'

Two studies tested the use of 'disease images' – photos of children experiencing severe symptoms of vaccine preventable diseases – as an intervention, aiming to shock or scare participants into changing their attitudes [42,54]. A similar strategy described by two papers was employing a dramatic narrative of a child's experience with a disease or graphic written descriptions of disease symptoms [33,54].

3.3.4. Use of humor

Three studies examined the use of humor in messages correcting or criticizing vaccine misinformation. One [57] tested a humorous, satirical text critiquing avoidance of MMR vaccination against a non-humorous version, while two studies [36,38] examined the effect of humor-based and logic-based corrections to misinformation tweets about the HPV vaccine.

3.3.5. Strength and certainty of message

Three studies examined the effect of communicating vaccine information with differing levels of intensity or uncertainty. Batteux et al [34] tested hypothetical government announcements that communicated either with certainty or uncertainty about COVID vaccine effectiveness. Similarly, Kerr et al's study [56] included an experiment trialling no caution, medium caution, and high caution messages about COVID vaccine safety and efficacy and the need to maintain protective behaviours after vaccination. Betsch and Sachse [58] also explored message intensity in their experiment, which assessed strongly or weakly negating either two or five typical antivaccination misinformation statements.

3.3.6. Misinformation warning

Two studies examined the effect of communications that alert or train individuals about the potential for misinformation. Tully et al [59] explored doing so on Twitter by including a tweet about spotting misinformation within a simulated Twitter feed that included misinformation tweets about influenza, while Ludolph et al's experiment [52] tested the effect of including a warning message about misinformation appearing in search results during Google search. Relatedly, educating and training parents to identify misinformation and to critically evaluate evidence was an aspect of the community nursing program described by Marcus [40].

3.3.7 wt. of evidence

Two studies, both considering how to address the misperception of vaccines causing autism, assessed the impact of communicating the weight of evidence surrounding this misperception. Dixon et al [31] compared articles that provided either a one-sided argument against the (false) autism-vaccine link, a 'false balance' article that presented arguments both for and against the link, and weight of evidence articles that presented both arguments but included statements underscoring the lack of both scientific evidence and consensus among scientists supporting a link between autism and vaccines. A study by van der Linden [60] similarly focused on the lack of scientific consensus supporting the supposed autism-vaccine link, using both written messages and pie charts to indicate scientific consensus that vaccines are safe.

3.3.8. Message source

Several studies manipulated the source of the message/intervention to identify the most effective 'messenger', rather than (or in addition to) the message content, considering factors such as the gender, credibility or trustworthiness of the message source [37,50,58,61].

3.3.9. Message timing

One study assessed the effect of the timing of interventions addressing misinformation. Jolley & Douglas [32] assessed whether reading an article with anti-conspiracy arguments about vaccines generally was more effective prior to ('inoculating') or following ('debunking') exposure to misinformation.

3.4. Objective 2: Identifying potentially effective strategies

To identify potentially effective communication strategies, studies were grouped by the above approaches and findings were tabulated in an effect direction plot [25] (Table 4). A summary of each approach's effect is displayed in Table 2. Five studies [40,41,44,48,51] did not assess or measure outcomes, and were excluded. Intermediate outcomes, such as perceived reliability or accuracy of messages or message sources, were not examined in this study. Results were mixed, with no intervention type showing clear and consistent positive or negative results across outcomes.

Table 3

Summary of communication interventions to address vaccine misinformation, by intervention format.

Intervention Format	Description of interventions
Print medium interventions	Pamphlets or booklets aimed to address misconceptions and increase knowledge about vaccines and related diseases using approaches such as question-and-answer formats [26], presenting common myths alongside established evidence countering the myth [38,39], or simply providing simple, comprehensible information statements about vaccines [40]. Study [41] described the development of a *fotonovela* (similar to a comic book, but using photographs) designed to address myths about the HPV vaccine. Another paper described an evidence-based vaccine magazine developed in response to a locally circulating anti-vaccine booklet that had been circulated in the same community [36].
Video & multi-media	Two studies assessed video interventions, while one trialled a voice-over PowerPoint presentation. One video took a corrective, fact-based approach to addressing common misconceptions about vaccines [42], while the second explained how COVID-19 mRNA vaccines work [43]. The PowerPoint addressed common concerns surrounding infant vaccines and was shown to vaccine-hesitant parents of infants at their first pediatrician visit [44].
In-person interactive interventions	Studies described in-person interactive educational interventions, focused on particular vaccines and targeted at specific groups. Ho 2017 [35] assessed the impact of a series of interactive sessions run by 'Health Ambassador' volunteers with senior citizens in Singapore that aimed to improve knowledge and attitudes about influenza, pneumonia, and their vaccines. Marcus 2020 [36] described different strategies used in a grassroots community-based nursing program that aimed to counter widespread misinformation about measles and the measles vaccine among the New York Orthodox Jewish community, including developing an evidence-based magazine for parents, hosting workshops, vaccine fairs, and provider trainings
Social media strategies	Several studies examined social media-based strategies and interventions. These were mostly trialled through experimental simulations, such as mock Facebook or Twitter feeds. Two studies tested responding to a misinformation tweet with a humor-based or logic-based correction tweet [32,34]. Similarly, two studies tested different comments responding to Facebook posts including vaccine-related myths or misinformation. Gesser-Edelsburg et al [31] trialled a brief, unequivocal message emphasizing MMR vaccination requirements as well as a lengthier, more empathetic response that provided information responding to vaccine fears and concerns; Sullivan [33] assessed corrective messages posted as Facebook responses, but manipulated the message source, testing different sources such as libraries and the CDC. Social media-based strategies also included testing Facebook's 'related links' functionality by following a post containing misinformation with links to two related stories that confirm and/or refute it [45] as well as a more proactive strategy of exposing participants to a 'news literacy' tweet about how to spot fake news within a simulated Twitter feed that also includes a tweet linking to a false story about the flu vaccine causing the flu [46].
Other web-based strategies & interventions	Several web-based interventions or strategies that did not involve social media were among the included studies. Ludolph et al [47] conducted an experiment in which experimenters manipulated Google search results to include an information box containing either basic or more difficult to comprehend information about vaccination, and/or a warning that 'false or misleading information' may be encountered during their search. Knight et al [37] described the development of a digital, web-based intervention – a 'chat bot' - that used interactive 'therapeutic dialogues' aimed to address COVID-19 vaccine hesitancy. An experiment by Betsch & Sachse [48] tested websites addressing vaccine-adverse effects; the experiment manipulated the extremity of risk negations as well as the source of the negation by showing information on the websites of a trusted government health institution or that of a pharmaceutical company. Another study conducted a content analysis of government websites informing the public about vaccines, and found debunking and answering common questions to be the most commonly used approaches [49].
News articles	Four studies experimented with different communication strategies countering misinformation within mock news articles that study participants read within online surveys. Stojanov (2015) examined the effect of countering general anti-vaccine misinformation with articles that either solely provided debunking information or debunking information alongside information explaining the conspiracists' motivation and the fallacies in the anti-vaccine information. Another explored "psychographic microtargeting" by developing fictional news articles that aimed to address MMR vaccine misinformation by targeting psychological traits thought to be linked to vaccine attitudes[29]. Dixon et al [27] tested how different journalistic approaches in covering the autism-vaccine link, including a false balance framing and articles that presented the weight of evidence against the link, affects personal beliefs about the link. Lastly, Jolley & Douglas [28] examined the timing of exposure to anti-conspiracy articles rather than message content; this study assessed the effects of exposure to corrective information, in article form, before or after exposure to misinformation presented in articles supporting general vaccine conspiracy theories.
Visual communications	Several studies explored communication strategies that utilized visuals such as images or charts to address misinformation. Pluviano et al [38] compared 3 approaches, including a 'visual correction' utilizing infographics to compare the risks of measles, mumps and rubella with the risk of vaccine side effects, as well as a 'fear correction' showing graphic pictures of unvaccinated children infected with the diseases. The use of graphic images of infected children was also tested by Nyhan et al [50], while two studies utilized visuals to convey medical consensus or the weight-of-evidence behind accurate vaccine information, with van der Linden et al [51] using pie charts that conveyed medical consensus that vaccines are safe ('descriptive norm') or that parents should be required to vaccinate their children ('prescriptive norm'), while Dixon et al [27] used photos of either a single or group of scientists within a fictional article. The *fotonovela* project [41] also employed the use of images.
Message manipulations	Pluviano et al [52] manipulated message source, testing the effects of corrective messages about a fictional disease and vaccine coming from sources deemed to be of high and low expertise and trustworthiness, while Kerr et al [53] assessed message length, testing the effect of short and long messages, as well as manipulating message content and trialling messages that communicated varying levels of caution about COVID vaccine efficacy. Most of these studies focused on message content or framing. Kerr et al [53] compared various different messaging strategies to communicate information and address concerns and misinformation about COVID-19 vaccines, including a 'factbox' format presenting benefits and harms, question-and-answer format, a message explaining the vaccine approval processes, and a "scientific mechanism message" explaining how mRNA vaccines work. Batteux et al [30] conducted an experiment on messaging around the COVID-19 vaccine, testing hypothetical government announcements that communicated either with certainty or uncertainty about the effectiveness of vaccines that were under development. Nyhan et al [50] tested four interventions for addressing misinformation about the MMR-autism link, including providing information explaining the lack of evidence for this link, information about the dangers of measles, mumps and rubella, a dramatic narrative about an infant almost dying of measles, and graphic images of children with the diseases. Vaughn & Johnson [54] compared the effects of a refutational text that directly addressed myths about influenza and the flu vaccine with an expository text that provided factual information without specifically addressing misinformation; Featherstone & Zhang [55] also tested refutational messages, comparing the use of conspiracy and uncertainty framings to counter measles/MMR misinformation. Ryan et al [56] compared a 'disease risk' framing, highlighting the risks of whooping cough in a brief story, with a 'myth busting' approach summarizing evidence refuting misinformation about adverse outcomes from the antenatal whooping cough vaccine; similarly, Nyhan & Reifler [57] compared a 'danger' message about influenza risks with a 'correction' message debunking the myth that the flu vaccine can cause the flu. Moyer-Guse et al [58] tested humorous and non-humorous texts that criticized the decision to not get the MMR vaccine because of the fear of adverse reactions.

Table 4
Intervention effect direction plots

Intervention Type	Author	Year	Vaccine	Intervention Description	Comparison Group	Belief in mis-information	Knowledge	Vaccine Attitudes/ Beliefs/ Hesitancy	Intention to vaccinate
DEBUNKING/ REFUTATIONAL	Featherstone & Zhang	2020	Measles/MMR	Refutational message: conspiracy framing	C			<> [1]	
	Featherstone & Zhang	2020	Measles/MMR	Refutational message: uncertainty framing	C			<> [1]	
	Stojanov	2015	General	Debunking message	C	<>			<>
	Stojanov	2015	General	Debunking message + information on fallacy and motives of conspiracists	C	▲			<>
	Vaughn & Johnson	2018	influenza	Refutational message	C		<>		
	Nyhan & Reifler	2015	influenza	Correction message	C	▲ [2]		▲ [2]	<> [2]
	Nyhan et al	2014	Measles/MMR	Correction message	C	▲		<> [3]	▼ [4]
	Pluviano et al	2017	General	Corrective pamphlet: myths vs facts	C	▼ [5]		<> [3]	▼ [5]
	Pluviano et al	2019	General	Corrective booklet: myths vs facts	C	▼ [6]		▼ [3,6]	<>
	Bode & Vraga	2015	autism-vaccine link	Facebook related news function	P			<> [7]	
	Trujillo et al	2020	Measles/MMR	Fictional news article explaining vaccines are safe and debunking autism link-psychographic microtargeting for those high in need for cognitive closure	C	<>			
	Ryan et al	2020	antenatal whooping cough	Mythbusting message	C			<> [9]	<>
MESSAGE TIMING	Jolley & Douglas	2017	General	Inoculation message (before exposure to misinformation)	C	▲		▲ [10]	▲
	Jolley & Douglas	2017	General	Debunking message (after exposure to misinformation)	C	<>		<> [10]	<>
MESSAGE SOURCE	Pluviano et al	2020	Fictional	Corrective message: high-expertise source	C				<>
	Pluviano et al	2020	Fictional	Corrective message: low-expertise source	C				<>
	Pluviano et al	2020	Fictional	Corrective message: high-trustworthiness source	C				<>
	Pluviano et al	2020	Fictional	Corrective message: Low-trustworthiness source	C				<>
	Sullivan	2019	influenza	Refutational message from CDC	C	▲			<>
	Sullivan	2019	influenza	Refutational message from other Facebook user	C	▲			<>
	Sullivan	2019	influenza	Refutational message from Public Library	C	<>			<>
	Sullivan	2019	influenza	Refutational message from American Library Association	C	<>			▼
MESSAGE INTENSITY	Betsch & Sachse	2013	Fictional	Non-credible source, strong risk negation	I			▼ [11]	▼
	Betsch & Sachse	2013	Fictional	Non-credible source, weak risk negation	I			▲ [11]	▲
	Betsch & Sachse	2013	Fictional	Credible source, strong risk negation	I			<> [11]	<>
	Betsch & Sachse	2013	Fictional	Credible source, weak risk negation	I			<> [11]	<>
	Batteux et al	2021	COVID-19	Certain announcement	I			▼ [13]	▼ [12]
	Batteux et al	2021	COVID-19	Uncertain announcement	I			▲ [13]	▲ [12]
	Betsch & Sachse	2013	Fictional	Strong risk negations	I			▼	<>
	Betsch & Sachse	2013	Fictional	Weak risk negations	I			▲	<>
	Betsch & Sachse	2013	Fictional	Number of risk negations	I			<>	<>
	Kerr et al	2021	COVID-19	Long message, no caution	C			<> [8]	<>
	Kerr et al	2021	COVID-19	Long message, medium caution	C			<> [8]	<>
	Kerr et al	2021	COVID-19	Long message, high caution	C			<> [8]	<>

Table 4 (continued)

Intervention Type	Author	Year	Vaccine	Intervention Description	Comparison Group	Belief in misinformation	Knowledge	Vaccine Attitudes/ Beliefs/ Hesitancy	Intention to vaccinate
	Kerr et al	2021	COVID-19	Short message, no caution	C			<>[8]	<>
	Kerr et al	2021	COVID-19	Short message, medium caution	C			<>[8]	<>
	Kerr et al	2021	COVID-19	Short message, high caution	C			<>[8]	<>
HUMOR CORRECTIONS	Moyer-Gusé et al	2018	Measles/MMR	Humorous message	I			▲[25]	
	Moyer-Gusé et al	2018	Measles/MMR	Non-humorous message	I			▼[25]	
	Vraga et al	2019	HPV	Humor-based correction	P	▲[14]			
	Kim et al	2020	HPV	Humor-based correction	I	▲[15]			
	Vraga et al	2019	HPV	Logic-based correction	P	▲[14]			
	Kim et al	2020	HPV	Logic-based correction	I	▲[15]			
INFORMATIONAL	Boyte et al	2014	HPV	Fotonovela	P		▲		
	Evers	2001	childhood vaccines	Q&A pamphlet	P		▲	▲	
	Ho et al	2017	influenza & pneumococcal	interactive educational sessions	P		▲	▲[16]	
	Kortum et al	2008	General	corrective fact-based video	P		▲		
	Witus & Larson	2021	COVID-19	Male-narrated informational video	C				▲
	Witus & Larson	2021	COVID-19	Female-narrated informational video	C				<>[17]
	Kerr et al	2021	COVID-19	Factbox	C			<>[18]	<>
	Kerr et al	2021	COVID-19	Q&A format	C			<>	<>
	Kerr et al	2021	COVID-19	Vaccine approval message	C			<>	<>
	Kerr et al	2021	COVID-19	Vaccine mechanism message	C			<>	<>
	Nyhan & Reifler	2015	influenza	Danger message	C	<>		<>[19]	<>
	Nyhan et al	2014	Measles/MMR	Message with information on disease risks	C	<>		<>[3]	<>
	Ryan et al	2020	antenatal whooping cough	Message with information on disease risks	C			<>[9]	<>
	Trujillo et al	2020	Measles/MMR	Fictional news article explaining autism causes- psychographic microtargeting for those high in need for cognitive closure	C	<>			
	Trujillo et al	2020	Measles/MMR	Fictional news article about non-needle vaccines - psychographic microtargeting for those high in needle sensitivity	C	▲			
	Pluviano et al	2017	General	Visual correction with infographics	C	<>		<>[3]	<>
MISINFORMATION WARNING	Ludolph et al	2016	General	Google box, basic info	C		<>[20]	<>[21]	
	Ludolph et al	2016	General	Google box, basic info + warning message	C		▲[20]	<>[21]	
	Ludolph et al	2016	General	Google box, complex info	C		▼[20]	▼[21]	
	Ludolph et al	2016	General	Google box, complex info + warning message	C		▼[20]	▼[21]	
	Ludolph et al	2016	General	Google box, warning message only	C		<>[20]	<>[21]	
	Tully et al	2020	influenza	News literacy tweet about spotting misinformation	C	▲[22]			
WEIGHT-OF-EVIDENCE	Dixon et al	2015	autism-vaccine link	News article with false balance	C	▼[23]			
	Dixon et al	2015	autism-vaccine link	News article explaining weight of evidence in text only	I	<>[23]			
	Dixon et al	2015	autism-vaccine link	News article explaining weight of evidence with group exemplar	I	▲[23]			
	Dixon et al	2015	autism-vaccine link	News article explaining weight of evidence with single exemplar	I	▲[23]			
	Dixon et al	2015	autism-vaccine link	News article with one-sided perspective	I	▲[23]			
	van der Linden et al	2015	autism-vaccine link	Medical consensus messages about vaccine safety and requirements	C	▲		▲[24]	

Table 4 (continued)

Intervention Type	Author	Year	Vaccine	Intervention Description	Comparison Group	Belief in mis-information	Knowledge	Vaccine Attitudes/ Beliefs/ Hesitancy	Intention to vaccinate
DISEASE IMAGES & SCARE TACTICS	Nyhan et al	2014	Measles/MMR	Disease images	C	▼		<>[3]	<>
	Pluviano et al	2017	General	Disease images	C	<>		▼[3]	<>
	Trujillo et al	2020	Measles/MMR	Fictional news article describing measles infection-psychographic microtargeting for those high in moral purity	C	▲			
	Nyhan et al	2014	Measles/MMR	Dramatic narrative	C	<>		▼[3]	<>

KEY

▲	Positive effect (improve knowledge/attitudes/vaccination intentions, reduce belief in misinformation)
<>	Mixed or no clear effect
▼	Negative effect (worsen knowledge/attitudes/intention to vaccinate; increase believe in misinformation)
▲ <> ▼	Sample size: n <100
▲ <> ▼	Sample size: n = 100–500
▲ <> ▼	Sample size: n>500

Comparison groups: C: Comparator is control group; **P**: Pre/post comparator; **I**: Intervention arms compared to one another

Notes

1 No clear effect on vaccine hesitancy (measure was 3-item composite measure of concern about MMR vaccine side effects), but improved general attitudes (3-item composite measure of attitudes towards having child receive MMR vaccine)

2 In subgroup analysis (low and high side effects concern), correction intervention significantly reduced false beliefs and safety concerns only for low side effects concern group. For intention to vaccinate, subgroup analysis found that correction intervention decreased intention among high side effects concern group.

3 Vaccine hesitancy measure was single item on perceived likelihood of MMR vaccine side effects

4 In subgroup analysis, correction message only significantly decreased intention to vaccinate among respondents with least favorable vaccine attitudes prior to intervention.

5 Belief in misinformation and intention to vaccinate significantly worse compared to control at time 2 (7 days after intervenion) only, and not at time 1 (immediately after)

6 Belief in misinformation and vaccine hesitancy significantly worse compared to control at time 2 (7 days after intervenion) only, and not at time 1 (immediately after)

7 Vaccination attitudes measure was 3-item composite measure of agreement with statements about vaccines causing autism, frequency of MMR vaccine side effects, and intention to vaccinate

8 Attitudes/beliefs measured with adapted versions of perceived efficacy and public importance subscales of Oxford COVID-19 vaccines beliefs scale; estimated % of cases prevented for additional measure of perceived vaccine efficacy. Vaccine hesitancy measured using 7 item Oxford Covid-19 Vaccine Hesitancy Scale. No caution messages (both short and long) improved attitudes/beliefs measure, but had no effect on vaccine hesitancy.

9 Vaccination attitudes measure was a 3-item composite measure of agreement that vaccination protects against and reduces risk of whooping cough

10 Vaccine hesitancy measure was an 8-item composite measure of agreement with statements about vaccines being dangerous

11 Vaccine hesitancy measured with 2 items on perceived risk and severity of vaccine side effects

12 Uncertain announcement was associated with a smaller decline in vaccination intention and effectiveness belief after receiving conflicting information, as compared to certain announcement

13 Vaccine hesitancy measured with single item of perceived vaccine effectiveness

14 Misinformation belief measured as percent agreement with statement about link between HPV vaccine and auto-immune symptoms

15 Measured with 6-item index of agreement with statements about HPV vaccine misperceptions

16 Measured with three items on perceived risk and benefits of influenza and pneumonia disease and vaccination

17 In subgroup analysis, female-narrated video was associated with decreased vaccination intention among political conservative respondents

18 Factbox intervention increased estimate of side effect frequency

19 Beliefs is single measure of perceived vaccine safety

20 Knowledge measured with validated scale of 9 true/false items about vaccinaiton; no statistical tests reporting pairwise comparisons; conservative assessments made based on figures

21 Attitudes and beliefs towards vaccination measured with 9 items on vaccination risks and benefits; perceived likelihood of severe side effects; no statistical tests reporting pairwise comparisons - made conservative assessments based on graphs

22 Measured with multiple items combined into an index of rated credibility of tweet claiming flu vaccine causes flu and flu-related deaths

23 Only false balance condition compared to control was reported; remaining intervention conditions compared to false balance condition

24 Attitudes/beliefs measured with 8 items combined into an index with items on support for vaccines; vaccine hesitancy measured with single item on level of concern about potential risks of vaccines

25 Vaccine hesitancy was 3-item measure. Humorous message indirectly reduced vaccine hesitancy by reducing emotional reactance to the message (as compared to non-humorous message); this effect was maintained among participants with greater pre-existing false beliefs about vaccines, whereas for participants with favourable vaccine attitudes, the non-humorous message was more effective.

Table A1
Sample descriptions of included studies.

Author	Year	Country	Sample Size	Sample Description	Vaccine intent measured for self or child/others
Batteux et al	2021	UK	328	UK residents; mean age 35; 71 % female; 65 % undergraduate degree or higher	self
Betsch & Sachse	2013	Germany	115/ 119	Experiment 1: Nonstudent community sample; mean age 34.2; 34.2 % male Experiment 2: mean age 33.1; 37.3 % male	child
Bode & Vraga	2015	US	524	American university students; mean age 20; 68 % female	child
Boyte et al	2014	US	22	Latina mothers of preteens in California; mean age 43.1	N/A
Brueggmann et al	2016	US	418	Spanish-speaking mothers; average age 46	child and self
Dixon et al	2015	US	371	U.S. respondents; mean age 32.8; 57 % male; 80.3 % white	N/A
Evers	2001	US	10	Postpartum mothers; 100 % African American; ages ranged 17–38; majority had 12th grade education	N/A
Featherstone & Zhang	2020	US	609	Mean age 35.8; 52 % male; 66.0 % White, 7.9 % African American, 15.6 % Asian, 7.4 % Hispanic; 59 % were parents; 43.4 % had a college degree	N/A
Gesser-Edelsburg et al	2018	Israel	243	Graduate students; 65 % in health professions; 82.7 % female; mean age 30	child
Ho et al	2017	Singapore	604	Seniors; median age 73; 34.3 % male; 85.8 % Chinese, 9.3 % Malay; 25.5 % secondary education or higher	N/A
Jolley & Douglas	2017	US	267/ 180	Study 1: U.S. residents; mean age 31.9; 36.5 % female; 50.4 % were parents Study 2: U.S residents; mean age 33.8; 54.3 % female; 36.6 % were parents	child
Kerr et al	2021	UK	2;097/ 2;217	Study 1: Mean age 43.2; 51.7 % female; median education of bachelors degree or equivalent; 87 % White ethnicity Study 2: mean age 46.33; 53 % female; median highest education of schooling to age 18; 88 % White ethnicity	self
Kim et al	2020	US	61	American university students; 37.7 % male; 44.3 % White; mean age 20	N/A
Knight et al	2021	UK	N/A	N/A	N/A
Kortum et al	2008	US	34	High school students; 50 % female; from school with 94 % Hispanic student body	N/A
Ludolph et al	2016	multiple	279	54.8 % male; 43.4 % from the U.S., 29.4 % from the UK, 18.6 % from Canada; 52 % college graduates or higher education; mean age 37.34	N/A
Marcus	2020	US	N/A	N/A	N/A
Moyer-Gusé et al	2018	US	187	U.S. parents of a child < 9 years; mean age 33.5	child
Nyhan & Reifler	2015	US	1000	U.S. adults; 21 % aged 18–29, 24 % 30–44, 28 % 45–59, 26 % 60+; 52 % female; 26 % college education or greater; 71 % White	self
Nyhan et al	2014	US	1759	U.S. parents with a child 17 or younger; 55.5 % female; 62 % White, 19 % Hispanic, 12 % Black; 31 % college graduate; 40 % 30–40 years	child
Pluviano et al	2020	Scotland	90	Undergraduate students; 72.2 % female; mean age 18.91	child
Pluviano et al	2017	Scotland & Italy	134	University students; 60.8 % female; mean age 25.35	child
Pluviano et al	2019	Italy	60	Italian parents; 88.3 % female; 31.7 % had an academic degree	child
Ryan et al	2020	England	282	Female residents of England at least 16 weeks pregnant; mean age 31; 82 % White British; 72 % university degree education or higher	self
Stojanov	2015	not reported	160	70.6 % female; 92.5 % urban residence; 81.9 % had a university degree or higher	child
Sullivan	2019	US	625	48.6 % female; 59.9 % 26–40 years old; 64.1 % had a four-year college education or higher	self
Trujillo et al	2020	US	7;019	American adults; 51 % female; mean age 46; 32 % had college degree; 66 % White, 12 % Black, 14 % Hispanic (weighted)	N/A
Tully et al	2020	US	1;214	Average age 37; average education of bachelor's degree; 54 % female	N/A
van der Linden et al	2015	US	206	American adults; 56 % male; 12 % 18–24 years, 23 % 35–44 years, 12 % 45–54 years, 12 % 55 + uears; 55 % had college degree or higher	child
Vaughn & Johnson	2018	US	64	Pre-service teachers and early career teachers; 87.5 % female; 51 % Caucasian, 9 % African American, 6 % Hispanic, 3 % Asian, 6 % multi-racial; average age 28	N/A
Vivion et al	2020	France & Canada	N/A	N/A	N/A
Vraga et al	2019	US	406	54 % male; 80 % white; median participant had an associate's degree	N/A
Witus & Larson	2021	US	1;632	Respondents located in the U.S.; 43.9 % female; 13.3 % 55 + years; 9.9 % Black; 66.6 % bachelor's degree or higher	self
Zangger Eby	2017	US	23	Parents of newborns	child

Fig. 2. Risk-of-bias assessments. Studies were assessed using RoB 2 tool for randomized trials, except as indicated. * indicates study was assessed using RoB 2 tool for cluster-randomized trials.

Five studies were assessed to be at high risk of bias, and the remaining 20 were judged to have some concerns for risk of bias (Fig. 2). Four uncontrolled before-and-after studies [30,39,47,49] were not formally assessed, but their findings are discussed.

3.4.1. Debunking/refutational interventions and messaging

Interventions and messaging that focused on debunking or refuting misinformation had mixed results; while three debunking interventions across four studies were found to lessen belief in misinformation, two interventions using myths vs facts pamphlets worsened belief in misinformation and another two approaches had no clear effect on belief in misinformation.[1] Only one small study examined knowledge as an outcome and found no clear effect [45]. Most studies on debunking interventions examined the effect on reported intention to vaccinate or broader measures of vaccine attitudes, beliefs, and hesitancy. Five debunking interventions had mixed or no clear effect on intention to vaccinate, and 2 experiments found debunking messaging to decrease vaccination intentions among some respondents (those with more hesitant attitudes towards vaccination at baseline) [53,54]. Most debunking interventions had mixed or no clear effect on broader vaccine attitudes. One experiment with two different refutational messages found that both tested strategies improved general attitudes towards the MMR vaccine, but had no clear effect on vaccine hesitancy, which was measured as concern over vaccine side effects [62]. Another found that a corrective message reduced false beliefs and safety concerns, but subgroup analysis revealed that this effect held only among respondents with less concern about side effects at baseline [53]. One of the studies testing a myths vs facts booklet found that the intervention worsened beliefs about MMR vaccine side effects [43].

3.4.2. Informational interventions/communication strategies

Informational interventions seemed to generally improve vaccine-related knowledge, with all four studies that assessed knowledge as an outcome reporting an improvement, though 3 of the 4 had very small samples [30,39,47,49]. Most (n = 9) of the informational interventions had mixed results or no clear effects on vaccine attitudes, though a question-and-answer pamphlet [30] and an interactive educational program [39] were found to improve attitudes, and an informational video, when narrated by a male voice, was found to increase reported intention to vaccinate [50]. The effect on belief in misinformation was assessed for five of the informational interventions with mixed or no clear effects found for four of the five [33,42,53,54]; however, a fictional news article providing information about needle-free methods for vaccine administration was found to reduce endorsement of misinformation among individuals high in 'needle sensitivity' or anxiety and discomfort related to needles and blood [33].

3.4.3. Disease images & other 'scare tactics'

Communications utilizing disease images and other dramatic approaches were largely ineffective. The interventions using photos of children experiencing severe symptoms of vaccine-preventable diseases worsened or had no clear effect on belief in misinformation and vaccine attitudes. The similar tactic of using a dramatic narrative about an infant almost dying of measles also backfired, increasing the perceived risk of severe vaccine side effects [54]. However, one study found that a news article including a parent's graphic description of their child's experience with measles decreased endorsement of vaccine-related misinformation among individuals high in 'moral purity', a psychological trait in

which decision-making is driven by feelings of disgust and trying to avoid contamination and disease [33].

3.4.4. Humor

Three studies examined the use of humor in messages correcting or criticizing vaccine misinformation. One assessed vaccine hesitancy, and found both humorous and non-humorous messages reduced vaccine hesitancy, but were more effective for different populations. The humorous, satirical message reduced vaccine hesitancy among participants that held more false vaccine beliefs at baseline, while the non-humorous message was found to be more effective among respondents that already held positive vaccine beliefs [57]. Two HPV vaccine studies [36,38] found that both humor-based and logic-based corrections reduced misperceptions, but that the logic-based corrections were found to be more credible and were more effective at reducing misperceptions.

3.4.5. Message intensity

'Stronger' messaging – negating a risk more strongly or communicating with more certainty – seems to backfire, with 2 studies finding such messaging to worsen vaccine hesitancy and intention to vaccinate, while communicating with uncertainty or weaker risk negations improved vaccine hesitancy and intentions relative to the stronger messages [34,58]. A third study found mixed results as to the impact of communicating the effectiveness of COVID-19 vaccines with varying levels of certainty on vaccine hesitancy, intentions, and beliefs; for example, messages that didn't caution that protective measures would be needed post-vaccination were associated with higher perceived vaccine efficacy, but this had no effect on vaccination intentions [56].

3.4.6. Misinformation warning

Two studies assessed strategies alerting participants to the potential for misinformation on Twitter [59] and during a Google search [52]. This appears to be a potentially promising approach; Tully et al [59] found belief in misinformation to decrease with a misinformation warning, while Ludolph et al [52] found that combining simple, comprehensible information about vaccines with a misinformation warning improved participant knowledge and attitudes; however, the effects of the misinformation warning alone are less clear.

3.4.7. Communicating weight-of-evidence/scientific consensus

Communicating the weight of evidence surrounding vaccines – that is, explaining which standpoint is supported by evidence and scientific consensus – may be a promising strategy. Two studies found that belief in misinformation was reduced when communicating weight of evidence alongside a visual exemplar (photo of scientist(s) for Dixon et al [31]; pie charts highlighting medical consensus for van der Linden et al [60]). Communicating weight of evidence without a visual exemplar had no effect on belief in misinformation [31], indicating the visual exemplar is a crucial piece of the intervention. Vaccine hesitancy and attitudes towards vaccines were also improved in van der Linden's experiment with messages highlighting medical consensus [60].

3.4.8. Timing of message

Only a single study specifically tested the timing of message interventions to see whether they are more effective prior to or following exposure to misinformation. Jolley & Douglas [32] found that anti-conspiracy arguments improved correct attitudes and increased intention to vaccinate when presented *before* participants read a conspiracy article, but not if reading it afterwards as a debunking measure.

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[1] Interestingly, in Bode & Vraga's study, while a debunking approach on Facebook of linking to articles that refuted misinformation had no effect on respondent attitudes, the same approach was successful for reducing misperceptions about a link between GMOs and illness.

3.4.9. Message source

Message source seems to be a salient factor in vaccination communications. Pluviano et al [61] found that misinformation corrections from sources deemed to be high- and low- expertise or trustworthiness did not affect vaccination intent, though corrections from high and low-expertise and high-trustworthiness sources decreased participants reliance on the misinformation; the authors concluded that trustworthiness of a message source was more important than expertise. Sullivan [37] tested refutational messages on Facebook from four different sources; one – the American Library Association – actually resulted in lower vaccination intentions, while messages from the CDC or another Facebook user resulted in reduced vaccine misperceptions. Two studies considered how message source interacts with other factors; Witus & Larson [50] found that while a male-narrated informational video led to improved vaccination intentions across the sample, the same video, when narrated by a female voice, was associated with decreased vaccination intentions among politically conservative participants. Betsch & Sasche [58] looked at message source and intensity together, and found that for a non-credible source, a message with weaker risk negations was more effective at improving vaccination intentions and hesitancy, while for credible sources, the intensity of risk negation communicated made no difference.

4. Discussion

Vaccine hesitancy is a key public health concern, contributing to disease outbreaks and interfering with epidemic control. Exposure to misinformation has been shown to decrease intent to accept a vaccine [13], highlighting the importance of identifying strategies that can effectively counter misinformation. This review demonstrates the wide range of communication strategies that have been tested and implemented to date, using a variety of formats – from interactive, in-person educational sessions to social media-based corrections of misinformation – and messaging approaches – including debunking, informational messages, using humor and manipulating the source or intensity of messages. Some strategies seem to be clearly ineffective: employing scare tactics, such as graphic images of children infected with vaccine preventable diseases, increased belief in misinformation [42,54]; communicating about vaccines with certainty – rather than acknowledging uncertainty around vaccine efficacy or risks – was also found to backfire [34,58]. Overall, promising communication studies include communicating the weight of evidence and scientific consensus around vaccines and related myths, utilizing humor, and incorporating warnings about encountering misinformation. The effects of trying to debunk misinformation, informational approaches, and communicating uncertainty may help with some outcomes, but have mixed results and should be investigated further.

The most common approaches taken by the reviewed studies – debunking and informational messaging – had very mixed effects across the considered outcomes. This is consistent with research that has shown that providing a dissenting message could backfire and reinforce pre-existing beliefs of a particular group [63]. One study however showed that "pre-bunking" that involved anticipating the 'myth' and providing the anti-conspiracy message in advance could however increase intention to vaccinate [32], in line with effective prophylactic approaches identified elsewhere[64].

Heterogeneity was also found within studies, with some trials finding that a certain intervention was effective at improving attitudes or vaccination intent among some sub-populations but not others. This underscores the complexity of vaccination behaviors and the myriad factors that can influence attitudes, hesitancy, and decision-making [65]. More actionably, this heterogeneity

highlights the need for communication strategies and interventions to be chosen and tailored in audience-specific ways. Political views, shown to be associated with COVID-19 vaccination rates [66], are important to consider for both the targeting and tailoring of communications interventions; for example, Witus & Larson [50] found that among politically conservative individuals, an educational video about COVID-19 vaccines could increase vaccination intentions if narrated by a male, but that there was a backfire effect with a female narrator; this difference wasn't seen among politically liberal participants. Strategies may work better or worse among individuals with different baseline attitudes towards vaccination or belief in misinformation; for example, Moyer-Guse et al [57] found that humor-based misinformation corrections were more effective at reducing vaccine hesitancy among participants holding more false vaccine beliefs, while non-humorous messages were more effective for those who already had positive beliefs towards vaccines. These findings illustrate that the design of interventions and communications strategies need to consider who, specifically, they are targeting and are likely to reach, and underscore the need for future trials to conduct rigorous sub-group analyses and understand the baseline beliefs and attitudes of respondents.

The body of evidence generated by this systematic review points to several important considerations for its interpretation and for future research. Firstly, many of the studies were randomized trials conducted as simulated situations unlikely to reflect how a communication strategy would be implemented in real-life; a messaging approach that works when an individual reads an article embedded in an online survey experiment may not have the same effect when translated into a mass media campaign. Only a handful of studies examined actual interventions as they would be realistically delivered, and most of these did not rigorously assess effectiveness. Additionally, none of the studies directly measured the effect of interventions on actual vaccine uptake, though many surveyed participants about vaccination intention. Future research in this arena should aim to conduct real-world piloting of interventions and measure resulting changes in uptake of vaccines, in addition to indicators such as vaccination intention, knowledge and belief in misinformation. Lastly, research must keep up with the ever-changing media landscape through which misinformation propagates; future studies should consider how to address misinformation spreading on other social media platforms, such as Instagram, WhatsApp, and TikTok [67], including how modifying search algorithm, ranking different type of evidence and sources of information, and reporting online misinformation may help address disinformation [68].

Our findings contribute to and build upon the existing body of literature on interventions for improving vaccination rates. A previous review [69] found that text messaging interventions, primarily for vaccine appointment scheduling and/or reminders, and immunization campaign websites were among the potentially effective 'new media' approaches to increasing immunization coverage; avenues such as incorporating humorous corrections of myths or sharing misinformation warnings as a part of text messaging interventions should be explored. A *meta*-analysis of social media-based health misinformation corrections found that debunking is an effective strategy – but that correcting misinformation related to infectious diseases is more difficult, which may explain the more heterogeneous effects found in this review [19]. A 2015 review of reviews [18] echoes our findings of there being a lack of strong evidence to specifically recommend any interventions; the authors noted that educational tools, such as pamphlets, had little or no effect on vaccine hesitancy, and highlights the need to understand groups' specific concerns, rather than seeking an intervention that will be universally effective.

This review has some limitations. Firstly, most studies were conducted in the United States, and thus findings should be applied to other settings with caution. Secondly, the literature search was conducted approximately-one year into the COVID-19 pandemic; future research should aim to assess more recent and long-term assessments of communication interventions, and search additional databases. Our searches were restricted to studies published in the English language and we did not search for grey literature. Notably, previous studies indicate that the exclusion of non-English articles has little effect on systematic review results [70,71].Data extraction was performed by a single study member, rather than cross-checked by a second team member as originally planned. We were also constrained by the body of literature included in this review. None of the included studies directly assessed vaccination uptake rates; intention to vaccinate was the most proximate outcome considered, but still may not accurately reflect actual vaccination behaviors; vaccination attitudes, knowledge, and hesitancy are even less closely tied to vaccine uptake. Lastly, the heterogeneity of the included studies –in terms of intervention type, targeted vaccine, study context, sample characteristics, and assessed outcomes – precluded any formal *meta*-analyses, and the narrative synthesis approach taken required subjective distillation and summarization of the included studies. Despite these limitations, this review's strengths include identifying communication strategies that should be avoided, scoping out the body of research in an underexplored area, and identifying key areas for future research.

5. Conclusion

Heightened vaccine hesitancy that has arisen with Covid-19 vaccines has put to the fore the need to address ubiquitous vaccine mis- and disinformation. This review provides evidence on some promising avenues for communication strategies for addressing misinformation, such as conveying the weight of evidence and scientific consensus around vaccines and related myths, utilizing humor, tailoring communications to specific target audiences, and incorporating warnings about encountering misinformation. Our findings question the effectiveness of commonplace interventions such as vaccine myths debunking, employing scare tactics, and communicating with certainty. There is an urgent need to develop and evaluate interventions to reduce hesitancy caused by mis- and dis-information and to directly measure their effect on the outcome of vaccine uptake, rather than assessing only distal outcomes such as knowledge or attitudes, in quasi-experimental and real-life contexts. Only then will it be possible to ensure that effective public health interventions such as vaccination benefit all.

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Data availability

No data was used for the research described in the article.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2022.12.059.

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