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Health misinformation: examining its presence and impact across communication contexts

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Health misinformation: examining its presence and impact across communication contexts

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Editorial: Health misinformation: examining its presence and impact across communication contexts

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KEYWORDS

health, misinformation, media, digital, global, disinformation

Editorial on the Research Topic
Health misinformation: examining its presence and impact across communication contexts

Modern technologies provide consumers unprecedented access to health information. Digital platforms give users the ability to locate immediate, customizable resources for addressing health needs. Although these dynamic media tools present opportunities to increase health literacy/consciousness, they also make consumers vulnerable to misleading or false health claims. While news of false political information arguably generates the most media attention, health misinformation is particularly harmful to individuals and society given the potential to provoke mistrust in both medical institutions/professionals and highly validated medical procedures. Ultimately, as false health content gets shared and reinforced through various information channels (face-to-face, traditional media, social media) this may lead individuals to engage in unproven, and at times dangerous, health behaviors. Public figures/influencers now use increasingly more sophisticated digital tools to exert significant influence on the health attitudes and behaviors of millions of individuals. At the time of this writing, a measles outbreak triggered in western Texas, USA has led to over 1,300 documented cases throughout the country [Centers for Disease Control (CDC), 2025]. Measles, a viral disease the U.S. declared eradicated 25 years ago, can lead to a variety of serious health conditions as well as death. In the aftermath of this outbreak, news reports highlight how both social media users and public figures are promoting unproven treatments, such as the consumption of cod liver oil and vitamin A. Although this highly contagious and deadline virus can be prevented through a safe and extremely effective vaccine (Moss and Griffin, 2006), increased access to alternative information sources preying on vaccine doubts as well as news sources offering false balance between credible and discounted claims may contribute to a decline in uptake. This case study reflects one of many recent examples where public health initiatives collide with increasingly more dynamic and influential forms of misinformation, thus posing challenges to the wellbeing of vulnerable populations.

This Research Topic "*Health misinformation: examining its presence and impact across communication contexts*" explores the global prevalence and impact of health misinformation highlighting the challenges faced by health care entities and opportunities to address this dilemma. The 10 articles selected present diverse findings across various cultural, social, and political contexts. Three of these articles examine user discernment

of accurate health information. In Wei et al.'s investigation "*Factors influencing user's health information discernment abilities in online health communities: based on SEM and fsQCA*" presents a unique model to address how personal judgments linked to online health communities drive the ability to "discern" accurate health information. The findings from this analysis offer critical theoretical and practical implications for health information seeking in this digital environment. Peng et al.'s experimental research, "*The media literacy dilemma: can ChatGPT facilitate the discernment of online health misinformation?*" compares ChatGPT to other media literacy tools in aiding individual efforts to identify true vs. false health content. The findings suggest that there are significant limitations to ChatGPT utility as a misinformation detection resource. Li et al.'s large-scale survey of Chinese citizens during the height of COVID-19, "*COVID-19 vaccine-related misinformation identification among Chinese residents during a regional outbreak*" provides a unique perspective on the role of information source judgments and geographical differences that drive COVID-19 misinformation detection skills.

Three of our other Research Topic selections explore concerns over user-generated health misinformation. Humprecht and Kessler's study "*Unveiling misinformation on YouTube: examining the content of COVID-19 vaccination misinformation videos in Switzerland*" highlights one case of the infodemic proliferating during COVID-19 (Islam et al., 2020). By identifying leading Swiss figures posting false vaccine information on YouTube, the authors provide a quantitative assessment of the prevalent misinformation strategies, including commercialization and emotionalization. Furthermore, many of the videos intersperse false information with scientific evidence, thereby increasing user engagement. Zhao et al. investigation of short online videos providing lung cancer information to Chinese adults—"*Current status of short video as a source of information on lung cancer: a cross-sectional content analysis study*"—analyzes the educational value of these non-traditional information sources. Results of this analysis raise questions on the validity of user-generated content, highlighting the importance of source expertise. Skarzauskiene et al.'s project, "*Profiling antivaccination channels in Telegram: early efforts in detecting misinformation*" address the troubling aspects of vaccine-related misinformation on Telegram as well tools to identify malicious content. The findings reveal important insights into how misinformation actors frame health crises, manipulate online conversations (i.e., testimonial strategies), and emotionally-driven language.

Bates et al. article "*Navigating misinformation and political polarization of COVID-19: interviews with Milwaukee, Wisconsin county public health officials*" provides an in-depth examination of the misinformation challenges faced by U.S. public health officials during the peak of the COVID-19 pandemic. The insights shared by these public health professionals offers lessons on attempts to combat both media misinformation and political polarization when trying to implement preventative health measures.

Pjesivac et al.'s study "*Examining conspiracy theory spillover in health communication arena: factors that impact COVID-19 conspiratorial beliefs and health-related behaviors*" indicates that general conspiracy beliefs drive more specific acceptance of COVID-19 related conspiracies. Examining the ramifications of this relationship through a sequential process, the researchers show that embracing general conspiracy theories indirectly contributes to less COVID-19-specific avoidance behavior by driving acceptance of COVID-19 conspiracy theories.

Finally, *two* systematic reviews are included in this Research Topic. Bhattacharya and Singh's research, "*Unravelling the infodemic: a systematic review of misinformation dynamics during the COVID-19 pandemic*" provide a comprehensive analysis of information gaps emerging during COVID-19. The research offers key analysis of technical, social and psychological factors facilitating the spread of COVID-19 misinformation. Furthermore, the authors provide a critical assessment of the effectiveness/limits of government regulation and public education in minimizing this infodemic. Alfred et al.'s systematic review, "*Drivers of vaccine mis/disinformation in the media: from personal beliefs to cultural dimensions*" differentiate between demand and supply side dynamics in mediated false vaccine information. The project highlights the influence of cultural dimensions (individualistic vs. collectivistic societies) in determining the main drivers of vaccine misinformation.

Overall, these 10 articles reflect the scope of global health misinformation across health contexts and modalities. As information tools become increasingly sophisticated, personalized, and accessible, the insights from this Research Topic can provide guidance to public health initiatives aimed at better educating and empowering citizens to make responsible health decisions.

Author contributions

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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COVID-19 vaccine-related misinformation identification among Chinese residents during a regional outbreak

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Objectives: Misinformation about the COVID vaccines poses a significant challenge to vaccination efforts in many countries. This study examined Chinese citizens' ability to correctly identify COVID-19 vaccine misinformation in geographic areas with and without a regional outbreak. We also investigated the associations between misinformation identification and information source usage, source trust, perceived information quality, and demographic characteristics.

Setting: The online survey was conducted in four cities from June 8th to 15th, 2021 in Guangdong Province, two of which were experiencing a regional surge of COVID-19 delta variant infections, and four cities in Hunan Province, a neighboring province largely unaffected.

Participants: A total of 4,479 individuals aged 18 and above completed the online questionnaire. Given survey length, those who finished the study under 5 min were excluded, resulting in a final sample of 3,800.

Outcome measurements: Misinformation identification, source exposure, source trust, and perceived information quality.

Results: Results showed slightly higher levels of correct misinformation identification in surge vs. non-surge areas. Trust in official information sources was positively associated with correct misinformation identification in full sample analysis, while trust in informal sources was negatively associated with the same outcome. Perceived information quality was positively associated with correct misinformation identification in the full sample.

Conclusion: Information providers in China should enhance the quality of the vaccine information they provide, and the Chinese public should balance their usage of different sources of information to acquire vaccine knowledge.

KEYWORDS

COVID-19 vaccine, misinformation identification, information source usage, information source trust, perceived information quality

1. Introduction

In May 2021, a large-scale outbreak caused by the coronavirus variant, Delta, happened in Guangzhou (1). This regional outbreak urged the Chinese government to speed up nationwide vaccination to better protect its population against the COVID-19 virus. However, China's COVID vaccines had only become widely available to the general public for about 3 months by that time (2). China's COVID control efforts were heavily focused on the promotion of daily preventative behaviors such as wearing masks, washing hands, and social distancing (3). There was a general lack of information about the vaccines, which left the door open for the growth and influence of misinformation (4–6). In China, in addition to official information sources, such as government-owned news outlets, informal sources such as interpersonal networks and social media also play an important role as information purveyors. Large amounts of misinformation and conspiracy theories exist in these sources (7–9). Heavy use of social media and other informal sources often leads to exposure to misinformation, which in turn may inflate risk perceptions about the vaccines, resulting in more negative attitudes toward vaccination (10, 11).

What kinds of misinformation or misunderstanding about the COVID-19 vaccines might have existed during the Guangzhou regional outbreak? How well were people able to identify misinformation when they saw it? Were there any differences in people's ability to identify vaccine-related misinformation between the surge areas (i.e., areas directly affected by the outbreak) and non-surge areas? How was misinformation identification associated with information source usage, trust in these sources, perceived information quality, and individual characteristics? This study aims to address these questions through a survey conducted during the outbreak of local residents from eight Chinese cities in two provinces in China.

2. Background

2.1. Misinformation

Health misinformation is defined as "a health-related claim of fact that is currently false due to a lack of scientific evidence" (12). Vaccine misinformation is mostly anti-vaccine in nature (13) and tends to arouse public fear and decrease vaccine confidence (14). Typical contents of vaccine misinformation include false vaccine safety and effectiveness claims, inaccurate information about vaccination procedures, conspiracy theories, and so on (15). Previous research about HPV, MMR, and other vaccines has generated ample evidence for the negative effects of misinformation on public risk perceptions, attitudes, and behaviors (16, 17). As COVID-19 swept through the world, misinformation regarding its causes, treatments, and mechanisms of spread has surged so much that the WHO declared COVID-19 an "infodemic" (18). A cross-national study of multiple countries, including China, showed vaccine-related misinformation to be a major theme of the COVID-19 infodemic (11). For example, misinformation against COVID-19 vaccines may increase confusion and hesitation concerning types of vaccines. The COVID-19 vaccines available to the Chinese public in 2021 were inactivated vaccines, which differ from other vaccines, such as the mRNA vaccines. False messages may impede individuals from taking necessary prevention by describing inactivated vaccines as totally ineffective. A growing body of literature has documented the deleterious effects of misinformation on vaccine-related attitudes and behaviors (19, 20). To effectively promote COVID-19 vaccines in China, it is important to know what types of misinformation are prevalent among the Chinese public and how well people in China are able to differentiate misinformation from accurate information about the vaccines.

Although COVID-19 is considered a national health crisis, severity of the situation may vary in different areas, partly due to China's strict health policies that have prevented regional outbreaks from spreading across cities or provinces. In this study, surge areas refer to places where a COVID-19 outbreak is currently occurring, while non-surge areas mean regions with relatively few or no confirmed cases of COVID-19. During a regional outbreak, people living in affected and unaffected areas face vastly different life circumstances and may hold different vaccine-related beliefs and perceptions. Prior studies indicated that the information demands and behaviors of the public may change during a crisis. For instance, individuals amid health emergencies might want more information to stay informed of the ever-changing situation (21). But the urgency to regulate negative emotions such as anxiety and fear could also lead them to neglect information quality (22), making them vulnerable to misinformation. Moreover, the content, type, and framing of information are likely to be different between surge and non-surge areas. Non-surge areas often tend to focus on the promotion of daily precautionary measures, whereas information in surge regions may more often adopt a crisis news framing or try to shift public attention during recovery (23, 24). With this in mind, this study intends to see if individuals' ability to identify vaccine-related misinformation would differ between surge and non-surge areas.

> *RQ1*: How well could Chinese residents identify misinformation about the COVID-19 vaccines during the Guangzhou regional outbreak?
>
> *RQ2*: Did the ability to identify vaccine-related misinformation differ between residents from surge and non-surge areas?

2.2. Information sources, trust, and perceived quality

In many ways, people's information sources can shape what they see and what they believe (25, 26). When it comes to vaccination, previous research revealed that the sources from which individuals obtained information played a crucial role in their vaccination attitudes. For instance, prior studies demonstrated that individuals exposed to traditional news sources took the disease more seriously and expressed stronger pro-vaccine attitudes, while individuals predominately depending on the Internet tended to show less confidence in vaccine safety and effectiveness (27–29). A study conducted in China in the early days of the pandemic showed that the more diverse the channels people use, the greater one's likelihood to hold correct perceptions, and the greater one's ability to identify misleading information (30). Exploring how individuals use and feel

about different information sources can thus inform the understanding of their perceptions and attitude toward vaccines (31, 32).

Health information can be obtained from many different sources, ranging from news organizations, social media, health professionals to interpersonal networks. Past research categorized sources of health information into formal and informal sources (33). Formal sources refer to those whose credibility is endorsed by health departments and professionals, for instance, government websites and health resources (34, 35). These sources are usually more reliable and trustworthy than non-official social media outlets and word of mouth. For example, research found that those who consulted physicians as the primary source of vaccine-related information had better knowledge and more positive vaccine attitudes (36, 37). Informal sources refer to non-governmental, alternative outlets, such as general social media sites and online search engines (33). Among all the information sources, social media appear to have carried the most misinformation about COVID-19 and COVID-19 vaccines (38–40), mostly from informal sources. Besides, there is also evidence that false information tends to travel faster and broader on social media (41, 42). The abundance of health information on social media has made it difficult for the public to verify information accuracy, impeding effective public health response (8, 43).

Based on existing literature, this study adopts the dichotomous categorization of information sources, namely official versus informal sources. This dichotomy is particularly relevant for the China context, where official channels are quickly established and tightly controlled by the government whenever a health emergency occurs. Moreover, in China, professional news agencies have stayed highly consistent with the government to deliver scientific and timely updates on COVID-19, due to the supervision of the government on news coverage during health emergencies (44). Hence, we include news organizations as official sources in this study. We are interested in learning whether the use of these two categories of information sources would show different patterns of associations with the public's ability to identify vaccine-related misinformation.

It should be noted that accessing information does not necessarily mean accepting it. Individuals' perceptions of information sources play a role in their impact. Trust in information sources is considered an essential precondition for information acquisition and positive responses toward the health advice offered by the relevant sources (45). Recent studies on COVID-19 found that trust in information sources positively predicts the adoption of protective behaviors and favorable vaccination attitudes (25, 46). On the other hand, lower trust in scientific institutions and government was found to be positively associated with misinformation beliefs in a recent longitudinal survey study (47).

In addition to trust, perceived quality of health information is also an important factor in information consumption and impact, particularly in the E-health era (48–50). Recent research has examined the quality of COVID-19 information (50–52). For example, Halboub et al. (50) assessed the quality and readability of web-based Arabic health information on COVID-19. Stern et al. (52) investigated the quality of web-based information about preventive measures and self-care methods at the beginning of the COVID-19 pandemic. While highlighting the importance of information quality, these studies were based on content analysis and did not explore the perceptions of information receivers.

In this study, we assess Chinese residents' use of different information sources, their trust in these sources, and their general perception of the quality of the information they have been receiving about the COVID-19 vaccines. The associations between these informational variables and the public's ability to identify vaccine-related misinformation constitutes another key interest of this research.

> *H1*: (a) Exposure to official sources is positively associated with the ability to identify misinformation, while (b) exposure to informal sources is negatively associated with the ability to identify misinformation.

> *H2*: (a) Trust in official sources is positively associated with the ability to identify misinformation, while (b) trust in informal sources is negatively associated with the ability to identify misinformation.

> *H3*: Perceived information quality is positively associated with the ability to identify misinformation.

2.3. Individual background factors

Past research showed that sociodemographic factors were significant predictors of vaccine knowledge and/or misinformation beliefs (36, 53, 54). For example, one study found that older adults people exposed to erroneous information regarding vaccines and COVID-19 in the media were more likely to hold misperceptions (55). Another study found that while income was unrelated to misinformation exposure, it was negatively associated with misinformation acceptance (56). Given that COVID-19 represents a particularly grave danger for those with preexisting conditions, individual health status might also have a role to play in people's ability to identify vaccine-related misinformation. Our last research question, therefore, investigates the relationships between misinformation identification and individual's sociodemographic background and general health status.

> *RQ3*: Was misinformation identification associated with sociodemographic factors and individual health status?

3. Methods

3.1. Study design and setting

A cross-sectional online survey was conducted in Guangdong Province and Hunan Province from June 8th to 15th, 2021. During this period, Guangdong was the center of the severe outbreak caused by the Delta variant, which clustered in the southern coastal area. Hunan, although adjacent to Guangdong to the north, was not affected. Four cities were chosen within each province to represent different levels of economic development. In Guangdong Province,

Guangzhou, Shantou, Maoming, and Meizhou were selected. In Hunan Province, Changsha, Changde, Chenzhou, and Huaihua were selected. Guangzhou and Maoming were categorized as surge areas and the rest of the cities non-surge areas.

The survey was distributed through wjx.cn, the largest online survey platform in China with a demonstrated record of generating high-quality survey data (36, 57). Ethics approval for the current study was obtained from the Social Science Ethics Committee of Jinan University.

3.2. Participants

Snowballing was a key mechanism in both types of recruitment. Given strict COVID regulations, data collection for this study took the form of an online questionnaire. Since the development level of different cities in China varies greatly, different strategies were used for recruitment and data collection.

Guangzhou and Changsha are provincial capital cities with large populations and relatively mature community organizations. Researchers used WeChat, the leading social media platform in China, to recruit participants. Each city was divided into two strata, urban and suburban. Within each stratum, four residential communities were selected, each having WeChat groups with high coverage of the community membership. Recruitment materials were posted in the WeChat groups, and those who agreed to take the survey could fill out the questionnaire either on their mobile phones or using their personal computers. Both Guangzhou and Changsha are home to many major universities, where the vast majorities of students live in dormitories on campus. To supplement the local sample, researchers also recruited college students through their WeChat groups.

In the other six relatively underdeveloped cities, community-based WeChat groups were less popular and unlikely to provide satisfactory coverage of the resident populations. In these cities, a two-prong strategy was used for recruitment. For younger working residents, we sent study invitations to WeChat groups of different businesses and work units. For older adults residents, we recruited local community volunteers to directly approach and invite older adults members of their communities to fill out the questionnaire.

A total of 4,479 individuals completed the questionnaire. Only residents aged 18 and above were allowed to participate in the study. Given survey length, those who finished the study under 5 min were excluded, resulting in a final sample of 3,800 (84.8% of the total finished sample).

3.3. Measures

3.3.1. Misinformation identification

Ten false vaccine-related statements were presented, and participants were asked to indicate each as true or false. All statements were extracted from authoritative health information platforms, including China Central Television (CCTV) News, one professional health consultation website (dxy.cn, akin to WebMD in the U.S.), and one major online rumor-busting platform in China.[1] While most of the statements were existing rumors and false information, a few were converted from factual information to expand the coverage of the misinformation test. In order to understand respondents' overall capacity to recognize misinformation, the statements concerned diverse aspects, including necessity (2 items), effectiveness (2 items), benefits (1 item), safety (2 items), procedure (1 item), and precautions (2 items) related to vaccination against COVID-19. Correct responses (1 point each) were summed into a total score representing participants' ability to identify vaccine-related misinformation.

3.3.2. Sources of COVID-19 vaccine information

Participants were asked about the frequency with which they were exposed to information about COVID-19 vaccines from nine different sources. Responses were indicated on a 5-point scale (1 = "never" to 5 = "frequently"). These nine sources were combined into two categories. One represented official sources with varying degrees of affiliation with the government, including traditional media, news media websites or apps, work unit/school, health resources, and community administrative agencies. The other was a group of informal sources, including online search engines, social media, short video platforms, and interpersonal sources. A usage index for each category was created by averaging the appropriate items.

3.3.3. Trust in COVID-19 vaccine information sources

On a 5-point scale (1 = "do not trust at all" to 5 = "deeply trust"), participants reported the level of trust they had in the same nine sources as in the previous measure. Similarly, these nine items were combined through averaging into two categories, one reflecting trust in official sources, the other trust in informal sources.

3.3.4. Perceived quality of COVID-19 vaccine information

Four items were adapted from Lee et al. (58) to assess perceived quality of the COVID-19 vaccine information participants had received, regardless of sources. The items tapped into information credibility, clarity, relevance, and timeliness (e.g., "The COVID-19 vaccination information I got is trustworthy"). A 5-point scale (1 = "strongly disagree" to 5 = "strongly agree") was used to record responses. A summary score was created by averaging across items.

3.3.5. Demographics and health status

Participants' gender, age, education, and income were measured following norms in demography research in China. Self-reported health status was measured on a 4-point scale: "excellent," "good," "fair," and "poor." The last two categories were later combined due to small group sizes, resulting in a three-level measure.

3.4. Analysis

Pearson chi-square and independent-sample t-test were used to examine the differences between participants from surge and non-surge areas in sample characteristics, misinformation identification, source exposure, source trust, and perceived information quality. A series of logistic regressions were conducted to predict correct identification of each misinformation statement based on source exposure, sources trust, perceived information quality, and

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demographic factors. The same set of covariates was also used in an ordinary least squares (59) regression to predict the total score of correct misinformation identification across the ten statements. All analyses were performed using SPSS v.28 (IBM).

4. Results

4.1. Sample characteristics

Sample characteristics are presented in Table 1. Of the final sample ($N = 3,800$), 1,386 (36.5%) were from surge areas, 2,414 (63.5%) were from non-surge areas. The sample was diverse in sociodemographic characteristics. Most participants were female (63.5%) and 85.4% of them were under 50 in age. More than half of the participants (53.6%) had a college degree or above. Most participants (83.2%) earned 10,000 yuan or less per month. The majority of the sample rated their current health as excellent (72.2%), while very few rated their health as fair or poor (7.0%). Compared to those from non-surge areas, participants from surge areas were slightly younger ($p < 0.001$), better educated ($p < 0.001$), earning a higher income ($p < 0.001$), and seeing themselves as in better health ($p < 0.001$). There was no difference between the two subsamples in terms of gender composition ($p = 0.742$).

4.2. Ability to identify misinformation

To answer RQ1, Table 2 presents the full sample's overall performance on misinformation identification, which showed reasonable competence. The mean score for the entire sample was 7.84 (SD = 1.69), meaning that, on average, participants were able to correctly identify about 8 out of the 10 misinformation statements. Specific to individual items, the rate of correct identification was excellent for items 2, 4, 5 and 6 (all above 90.0%), while relatively poor for item 3 (57.0%) and item 9 (38.3%).

4.3. Differences between surge and non-surge areas

4.3.1. Differences in misinformation identification

Results answering RQ2 are also presented in Table 2. As shown, there was a significant difference in the mean scores for misinformation identification between surge areas and non-surge areas ($M = 7.92$ vs. 7.78, $p = 0.012$). For individual items, significant differences were observed for item 4 and item 8. For item 4, the rate of correct identification was 97.4% for surge areas and 94.3% for non-surge area ($p < 0.001$). For item 8, the rate of correct identification was 97.7% for surge areas and 88.1% for non-surge areas ($p < 0.001$). No significant difference was found for the other items.

TABLE 1 Sample characteristics.

	Entire sample (N = 3,800) %	Surge areas (N = 1,386) %	Non-surge areas (N = 2,414) %	p[a]
Gender				0.742
Male	36.5%	36.2%	36.7%	
Female	63.5%	63.8%	63.3%	
Age				<0.001
18–29	25.7%	23.7%	27.3%	
30–39	30.4%	35.2%	26.6%	
40–49	29.3%	27.0%	31.2%	
50+	14.6%	14.2%	14.9%	
Education level				<0.001
High school or less	23.6%	17.4%	28.4%	
Associate degree	22.8%	21.5%	23.8%	
College graduate	46.9%	53.0%	42.1%	
Postgraduate	6.7%	8.1%	5.7%	
Monthly income				<0.001
¥0–1,000	13.9%	13.2%	14.4%	
¥1,001–5,000	36.0%	27.3%	42.8%	
¥5,001–10,000	33.3%	33.0%	33.6%	
¥10,001+	16.8%	26.6%	9.2%	
Health status				<0.001
Excellent	72.2%	77.2%	68.3%	
Good	20.8%	17.8%	23.2%	
Fair or poor	7.0%	5.0%	8.5%	

[a]Pearson chi-square test between surge and non-surge areas.

TABLE 2 Misinformation identification.

Items	Entire sample (*N* = 3,800) %	Surge areas (*N* = 1,386) %	Non-surge areas (*N* = 2,414) %	*p*[a]
(1) There is no need to get vaccinated as long as I take precautionary measures like wearing masks, washing hands, and keeping social distance	72.6	72.2	72.8	0.710
(2) I do not need to get vaccinated now that most people around me have been vaccinated	96.1	96.3	95.9	0.502
(3) The domestic vaccine is an inactivated virus vaccine with a period of protection of only half a year	57.0	58.3	56.1	0.176
(4) I do not need to wear masks anymore after vaccination	95.7	97.4	94.3	<0.001
(5) The COVID-19 vaccine is no longer effective now that the COVID-19 virus has mutated	96.0	96.0	96.0	0.984
(6) Getting COVID-19 vaccine often causes severe adverse reactions	92.3	92.9	91.9	0.267
(7) People aged 60 and above are not suitable for COVID-19 vaccination	73.5	73.9	73.2	0.629
(8) I can get the second dose of COVID 19 vaccine 10 days after the first dose	89.7	91.7	88.1	<0.001
(9) Patients with chronic diseases such as hypertension and diabetes are not advised to take COVID-19 vaccine	38.3	39.1	37.6	0.354
(10) Xiaoming was bitten by a dog 3 days after receiving his first dose of COVID 19 vaccine, and should not be vaccinated against rabies for the time being	72.7	73.8	71.9	0.201
Mean # of correct responses (60)	7.84 (1.69)	7.92 (1.66)	7.78 (1.70)	0.012

[a]Pearson chi-square test between surge and non-surge areas.

4.3.2. Differences in informational variables

Table 3 presents descriptive statistics on exposure to different sources of COVID vaccine information, trust in these sources, and perceived quality of the vaccine information received for the full sample. It also shows the differences between surge and non-surge areas. As indicated in Table 3, participants from surge and non-surge areas reported similar levels of exposure to COVID vaccine information from official ($M = 3.63$ vs. 3.65, $p = 0.457$) and informal sources ($M = 3.84$ vs. 3.84, $p = 0.816$). They also had similar levels of trust in official sources ($M = 4.20$ vs. 4.18, $p = 0.350$) and perceived information quality ($M = 4.26$ vs. 4.32, $p = 0.063$). Participants from surge areas reported slightly lower levels of trust in informal sources ($M = 3.61$ vs. 3.66, $p = 0.048$), the only difference that reached statistical significance among the information variables.

4.4. Correlates of misinformation identification

4.4.1. Individual misinformation items

H1–H3 and RQ3 asked about factors associated with the respondents' ability to identify COVID-19 vaccine misinformation. Table 4 presents the logistic regressions examining the relationships

TABLE 3 Source exposure, source trust, and perceived information quality.

	Entire sample (*N* = 3,800)	Surge areas (*N* = 1,386)	Non-surge areas (*N* = 2,414)	*p*[a]	Alpha
	Mean (SD)	Mean (SD)	Mean (SD)		
Exposure to official sources[b]	3.64 (0.90)	3.63 (0.89)	3.65 (0.91)	0.457	0.85
Exposure to informal sources[c]	3.84 (0.81)	3.84 (0.80)	3.84 (0.82)	0.816	0.77
Trust in official sources[b]	4.19 (0.70)	4.20 (0.69)	4.18 (0.71)	0.350	0.92
Trust in informal sources[c]	3.63 (0.83)	3.61 (0.83)	3.66 (0.82)	0.048	0.89
Perceived information quality	4.29 (0.80)	4.26 (0.80)	4.32 (0.79)	0.063	0.97

[a]Independent sample *t*-test between surge and non-surge areas.
[b]Official sources: traditional media, news media sites or apps, work unit/school, health resources and community.
[c]Informal sources: search engines, social media, short video platforms and interpersonal sources.

between correct identification of each misinformation statement and demographics, health status, source usage, source trust, and perceived information quality. To further investigate RQ2, place of residence (surge vs. non-surge areas) was also included in the models. Results showed complex relationships between sociodemographic factors and the ability to identify specific misinformation items. For example, those who answered item 3 correctly were less likely to be 30 or older, more likely to have higher education levels, less likely to report good (vs. excellent) health, and less likely to report a monthly income of ¥1,001–5,000 (vs. ¥0–1,000). Those who answered item 9 correctly were more likely to be female, aged 50+ (vs. 18–29), and less likely to have a monthly income of ¥1,001–5,000 (vs. ¥0–1,000), and more likely to report fair or poor (vs. excellent) health condition. And those who answered item 7 correctly were more likely to be 30 or older and hold a postgraduate degree (vs. high school or less).

As for the information variables, trust in official sources was positively associated with the correct identification of item 1 (OR = 1.390, $p < 0.001$), item 2 (OR = 2.075, $p < 0.001$), item 3 (OR = 1.185, $p = 0.019$), item 5 (OR = 2.325, $p < 0.001$), item 6 (OR = 1.473, $p = 0.004$), item 7 (OR = 1.186, $p = 0.035$), item 9 (OR = 1.169, $p = 0.037$) and item 10 (OR = 1.404, $p < 0.001$). On the other hand, trust in informal sources was negatively associated with the correct identification of item 2 (OR = 0.528, $p < 0.001$), item 4 (OR = 0.564, $p < 0.001$), item 5 (OR = 0.610, $p = 0.006$), item 6 (OR = 0.710, $p = 0.006$) and item 10 (OR = 0.817, $p = 0.003$). Exposure to official sources was positively associated with the correct identification of item 7 (OR = 1.147, $p = 0.029$) and item 9 (OR = 1.118, $p = 0.050$), but negatively associated with the correct identification of item 1 (OR = 0.798, $p < 0.001$) and item 2 (OR = 0.672, $p = 0.015$). Exposure to informal sources was unrelated to any of the outcomes. Moreover, perceived information quality was positively associated with the correct identification of item 1 (OR = 1.134, $p = 0.039$), item 2 (OR = 1.365, $p = 0.018$), item 4 (OR = 1.372, $p = 0.010$), item 5 (OR = 1.504, $p = 0.001$), item 6 (OR = 1.516, $p < 0.001$), item 7 (OR = 1.240, $p < 0.001$), and item 8 (OR = 1.321, $p < 0.001$). Finally, surge area participants performed better on item 4 (OR = 2.014, $p < 0.001$) and item 8 (OR = 1.435, $p = 0.002$) than those from non-surge areas.

4.4.2. Total score

To further examine H1–H3 and RQ3, the same set of predictors shown in Table 4 were also used in an OLS regression to predict the total score of correct responses for the misinformation test. As shown in Table 5, exposure to COVID-19 vaccine information from official sources ($\beta = -0.026$, $p = 0.277$) and from informal sources ($\beta = -0.021$, $p = 0.404$) were unrelated to the total score of correct responses. H1 was rejected. Trust in COVID-19 vaccine information from official sources was positively associated with the total score ($\beta = 0.141$, $p < 0.001$), whereas trust in informal sources was negatively associated with the total score ($\beta = -0.061$, $p = 0.010$). Both H2a and H2b were supported. Furthermore, perceived quality of COVID-19 vaccine information emerged as a positive predictor ($\beta = 0.095$, $p < 0.001$). Hence, H3 was supported. Whether participants were from surge areas or non-surge areas was not associated with the total score ($\beta = 0.023$, $p = 0.162$).

As for demographic factors and health status, female participants scored higher than male participants ($\beta = 0.052$, $p = 0.002$). Higher education was in general positively related to the total score. Compared to those with a high school or lower education, each of the higher education level was associated with stronger performance on the misinformation test: associate degree ($\beta = 0.082$, $p = 0.003$), college graduate ($\beta = 0.076$, $p < 0.001$), postgraduate ($\beta = 0.130$, $p = 0.001$). In terms of monthly income, participants who earned 5,000–10,000 yuan per month scored higher than those earning 1,000 yuan or less ($\beta = 0.057$, $p = 0.037$). Age and health status were unrelated to the total score. There was also no difference between surge and non-surge areas in this model.

5. Discussion

This study examined Chinese residents' ability to correctly identify misinformation about COVID-19 vaccines during the first outbreak caused by the Delta variant in China in 2021. We analyzed how participants from surge vs. non-surge areas performed on a misinformation identification test, in terms of both item-specific performance and overall performance across the 10-item test. We also examined the relationships between misinformation identification

TABLE 4 Logistic regression predicting correct identification of individual misinformation items.

	Item1		Item 2		Item 3		Item 4		Item 5		Item 6		Item 7		Item 8		Item 9		Item 10	
	OR	*p*	OR	*p*	OR	*p*	OR	*p*	OR	*p*	OR	*p*	OR	*p*	OR	*p*	OR	*p*	OR	*p*
Gender																				
Male	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
Female	1.215	0.013	1.339	0.097	1.005	0.941	1.582	0.006	1.118	0.533	1.154	0.280	1.112	0.185	1.154	0.212	1.222	0.006	1.073	0.372
Age																				
18–29	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
30–39	1.057	0.605	0.934	0.793	0.816	0.038	0.641	0.088	0.619	0.096	0.804	0.251	1.512	<0.001	0.962	0.812	0.888	0.237	1.114	0.327
40–49	1.226	0.066	0.896	0.676	0.699	<0.001	0.578	0.035	0.475	0.009	0.805	0.262	1.707	<0.001	0.914	0.579	1.022	0.833	0.907	0.379
50^{+}	1.040	0.767	0.585	0.059	0.791	0.052	0.498	0.017	0.352	<0.001	0.644	0.041	2.162	<0.001	0.845	0.377	1.475	0.001	0.709	0.008
Education level																				
High school or less	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
Associate degree	1.063	0.574	0.920	0.727	1.267	0.019	1.103	0.667	0.976	0.923	1.540	0.014	1.004	0.975	1.354	0.051	1.192	0.089	1.290	0.021
College graduate	1.295	0.011	1.269	0.312	1.242	0.019	1.327	0.201	0.929	0.759	1.785	<0.001	0.997	0.977	1.470	0.008	1.099	0.325	1.121	0.260
Postgraduate	1.305	0.140	0.845	0.658	1.416	0.030	0.729	0.379	1.356	0.490	1.723	0.079	1.578	0.017	1.567	0.097	1.306	0.100	1.331	0.127
Monthly income																				
¥0–1,000	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
¥1,001–5,000	1.070	0.570	1.391	0.221	0.781	0.028	1.559	0.079	1.119	0.702	1.232	0.274	0.947	0.653	1.248	0.186	0.766	0.019	1.156	0.222
¥5,001–10,000	1.202	0.159	1.480	0.185	0.870	0.251	1.670	0.069	1.453	0.253	1.664	0.020	1.058	0.668	1.387	0.080	0.976	0.841	1.478	0.003
¥10,001^{+}	1.200	0.239	1.168	0.652	0.798	0.113	2.094	0.038	0.900	0.770	1.332	0.267	1.061	0.703	1.310	0.232	0.952	0.733	1.608	0.003
Health status																				
Excellent	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
Good	1.092	0.352	0.925	0.710	0.841	0.036	0.864	0.456	0.687	0.056	0.972	0.855	0.968	0.732	1.068	0.627	1.168	0.067	1.230	0.030
Fair or poor	0.985	0.919	1.451	0.330	1.119	0.406	0.946	0.856	0.858	0.628	1.083	0.743	1.204	0.247	1.082	0.713	1.528	0.002	0.918	0.550
Information-related factors																				
Exposure to official sources[a]	0.798	<0.001	0.672	0.015	0.956	0.418	0.861	0.307	0.821	0.211	0.847	0.135	1.147	0.029	1.036	0.696	1.118	0.050	0.933	0.273

(Continued)

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TABLE 4 (Continued)

	Item1		Item 2		Item 3		Item 4		Item 5		Item 6		Item 7		Item 8		Item 9		Item 10	
	OR	*p*	OR	*p*	OR	*p*	OR	*p*	OR	*p*	OR	*p*	OR	*p*	OR	*p*	OR	*p*	OR	*p*
Exposure to informal sources[b]	0.919	0.245	1.251	0.211	0.970	0.643	1.228	0.214	1.136	0.467	1.076	0.560	0.867	0.052	0.876	0.213	0.945	0.391	1.047	0.531
Trust in official sources[a]	1.390	<0.001	2.075	<0.001	1.185	0.019	1.345	0.105	2.325	<0.001	1.473	0.004	1.186	0.035	1.121	0.329	1.169	0.037	1.404	<0.001
Trust in informal sources[b]	0.970	0.649	0.528	<0.001	0.986	0.817	0.564	<0.001	0.610	0.006	0.710	0.006	0.950	0.460	0.877	0.196	1.059	0.343	0.817	0.003
Perceived information quality	1.134	0.039	1.365	0.018	1.085	0.136	1.372	0.010	1.504	0.001	1.516	<0.001	1.240	<0.001	1.321	<0.001	0.976	0.662	1.051	0.415
Surge areas vs. non-surge areas	0.923	0.299	1.083	0.657	1.059	0.412	2.014	<0.001	0.989	0.953	1.034	0.800	1.012	0.876	1.435	0.002	1.058	0.429	1.000	0.997
Nagekkerke *R* square	0.026		0.050		0.021		0.059		0.087		0.055		0.048		0.027		0.029		0.034	

[a]Official sources: traditional media, news media sites or apps, work unit/school, health resources and community.
[b]Informal sources: search engines, social media, short video platforms and interpersonal sources.

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TABLE 5 OLS regression model predicting the total score for misinformation test.

	Unstandardized coefficient	95% CI lower bound	95% CI upper bound	Standardized coefficient	*p*
Gender					
Male	Ref.				
Female	0.182	0.069	0.295	0.058	0.002
Age					
18–29	Ref.				
30–39	−0.012	−0.167	0.143	−0.003	0.879
40–49	−0.030	−0.189	0.129	−0.008	0.712
50+	−0.025	−0.217	0.167	−0.005	0.799
Education level					
High school or less	Ref.				
Associate degree	0.241	0.080	0.401	0.06	0.003
College graduate	0.256	0.107	0.404	0.076	<0.001
Postgraduate	0.417	0.163	0.671	0.062	0.001
Monthly income					
¥0–1,000	Ref.				
¥1,001–5,000	−0.014	−0.191	0.163	−0.004	0.879
¥5,001–10,000	0.203	0.013	0.394	0.057	0.037
¥10,001+	0.152	−0.072	0.377	0.034	0.183
Health status					
Excellent	Ref.				
Good	0.163	−0.051	0.377	0.007	0.136
Fair or poor	0.029	−0.104	0.162	0.025	0.665
Exposure to official sources[a]	−0.049	−0.138	0.039	−0.026	0.277
Exposure informal sources[b]	−0.044	−0.146	0.059	−0.021	0.404
Trust in official sources[a]	0.337	0.221	0.453	0.141	<0.001
Trust in informal sources[b]	−0.125	−0.220	−0.030	−0.061	0.010
Perceived information quality	0.200	0.112	0.288	0.095	<0.001
Surge areas vs. non-surge areas	0.079	−0.032	0.190	−0.026	0.162
Adj. R^2	0.036				

[a]Official sources: traditional media, news media sites or apps, work unit/school, health resources and community.
[b]Informal sources: search engines, social media, short video platforms and interpersonal sources.

and sociodemographic characteristics, perceived health status, and information-related factors.

5.1. Misinformation identification

To assess the sample's ability to identify COVID-19 vaccine misinformation, we developed a 10-item test that included the most current and widely circulated inaccurate information, rumors, and conspiracy theories. The overall performance of the sample on the test was adequate, averaging 8 out of 10. However, some misinformation items appeared to be more widely believed than others. Many participants endorsed the ideas that vaccination is unsafe for people with chronic diseases such as hypertension and diabetes, and that the domestic vaccine provides protection against the virus for only 6 months. Participants from surge and non-surge areas performed equally well, as both groups correctly identified most of the misinformation statements as false. However, notable differences were also found with specific misinformation items. Participants from surge areas were more likely to correctly reject the ideas that vaccination is

unnecessary as long as one takes precautionary measures, and that one could get the second vaccination shot just ten days after the first one. This indicates that people from surge areas had better knowledge on these issues than those from non-surge areas.

5.2. Factors associated with misinformation identification

In our study, neither exposure to official sources nor exposure to informal sources was associated with the total number of correct responses in the misinformation identification task. Exposure to informal sources was also unrelated to performance on specific misinformation items. However, exposure to official sources was a significant predictor of correct responses to several specific misinformation items. It positively predicted correct responses on items about the vaccines being unsafe for people over 60 or with chronic diseases. On the other hand, it also negatively predicted correct responses on items about not needing vaccination as long as precautionary measures are taken or when other people around oneself have already been vaccinated. This latter finding is somewhat different from previous studies that found mainstream media and government sources to have consistently positive impact on knowledge and beliefs (25, 31). One possibility might be that China's success in containing the epidemic has resulted in complacency among the public. At the time of the study, the initial national epidemic was already well under control. Although regional outbreaks still happened occasionally, they were relatively small in scale and were often stamped out quickly with the government's swift action. Therefore, although exposure to official sources improved the public's vaccination knowledge in some regards, it might have also lowered the perceived importance of and need for vaccination as a result of consistently positive coverage during the pandemic.

In our study, trust in official sources was positively associated with correct responses on eight misinformation items, and trust in informal sources was negatively associated with correct responses on five items. The same pattern of associations was also observed with the total score of misinformation identification. These findings are consistent with previous studies (25, 46). It appears that, in China, trust in official sources can contribute to the public's ability to distinguish false from factual information, while trust in informal sources can lead to greater belief in misinformation. Since trust is a precondition for acceptance, these findings further suggest that adopting scientific and factual information from official sources may improve individuals' vaccine knowledge and intention, while believing in rumors and conspiracy theories circulating on informal and online platforms can contribute to vaccine hesitancy (8).

Consistent with our findings on trust, we found that perceived information quality was also a positive correlate of misinformation identification. When people perceived the COVID vaccine information they received to be of higher quality, their ability to discern false information also improved. Granted, perceived information quality is not the same as actual information quality. But there is reason to believe that perceptions of information quality are driven at least in part by the actual quality of the information people receive through sources of their choice. This suggests that a critical strategy to fight against misinformation about COVID vaccines is to enhance the general quality of the information available to the public. While this may sound like a commonsensical idea, its importance cannot be overestimated. After all, the "infodemic" is all about competition between different kinds of information. The more accurate information is out there, the less the room and opportunities for misinformation to take root. Moreover, equipped with accurate information and sound knowledge, people will also be better able to fend off misinformation when under assault and maintain their ability to make truly informed decisions about their vaccination and other self-protective measures.

The pattern of associations between sociodemographic factors and misinformation identification was complex in our data, demonstrating uneven vulnerability to the influence of misinformation across Chinese society. Certain groups of people, particularly women and those with lower education levels and lower income, appeared to be particularly susceptible to misinformation. These findings point to a critical need for targeted dissemination of high-quality information among these vulnerable groups (52).

5.3. Information sources: surge vs. non-surge areas

During times of uncertainty like a disease outbreak, people rely heavily on media and interpersonal sources to appraise personal and collective risk and to inform decision making. In this study, exposure to official and informal sources of COVID vaccine information was at similar levels for participants from surge and non-surge areas. This indicates that personal proximity to the outbreak did not make a significant difference in how much people used various types of sources. From another angle, this suggests that both official and informal sources were important information providers regardless of local outbreak status. In China, official sources such as government-owned media and professional health organizations generally provide more reliable and accurate information (61), but their information delivery is not always timely due to policy and procedural constraints. By contrast, informal sources such as social media and personal networks are easier and faster to access, even though the quality of the information disseminated through these channels may not always be unimpeachable. It appears that, during the outbreak, each type of information sources had some advantages to offer and people in both surge and non-surge areas had settled on a balanced diet to fulfill their information needs.

It is important to note that source usage and trust are two different matters in health information acquisition. Our results showed that trust in official sources was higher than that in informal sources in both surge and non-surge areas. This is unsurprising and consistent with previous evidence that people generally put more trust in professional and authoritative sources than in lay media or interpersonal sources (62). Our result also showed that trust in informal sources in surge areas was significantly lower than in non-surge areas. When the outbreak happened, people in surge areas were facing a much more urgent need to make vaccination decisions to protect themselves. In other words, perceived risk and urgency might have affected trust in information sources. When facing high risk and the need to make an important self-protective decision, people relied more on

information that they believed to be accurate, and placed less trust in unverified information sources.

5.4. Practical and theoretical implications

This study yields several practical implications for COVID vaccine promotion in China and globally. First, we suggest information providers to promote accurate knowledge and reducing public uncertainty about the COVID-19 vaccines (36). Both official and informal sources, should strive to enhance their information quality and reduce, if not eliminate, the circulation of misinformation on their platforms. Second, our study reveals that trust is a more critical factor in the public's ability to recognize and fend off misinformation than simple exposure. Intervention efforts should look to exploit the existing trust structure in the informational environment to boost the impact of their messages. There should also be efforts to build and maintain trust in intervention-owned information outlets, such as campaign websites, to ensure that the public can access and utilize accurate information about the COVID-19 vaccines without undue concerns. Third, health promotion should pay more attention to the role of media use and the public's media literacy. The findings in this study indicate that helping individuals to identify credible information sources and scientific facts in a complex media environment is crucial for vaccination programs. Besides developing intervention-specific information outlets, we encourage health promotion to be more active on media platforms commonly used by the public and ensure that reliable health information can reach the target audiences. While engaging social media and/or community networks, care should be taken to address the potential muddling of irrelevant and contradictory misinformation circulating in the same spheres. Finally, at times of regional (or larger-scale) outbreak, heavier reliance on high trust sources should prove most beneficial in raising awareness, keeping communities informed, weeding out misinformation, and mobilize appropriate actions such as getting vaccination.

Recent research acknowledges the increasing significance of information-related factors in health issues (63, 64). Various theories, such as the comprehensive model of information seeking and theory of motivated information management, have emerged to illuminate factors driving information behaviors (65, 66). Our work indicates that individuals' trust in professional sources and perceived information quality are essential to individuals' ability to resist false messages. To the extent that misinformation identification is an increasingly important form of information management in the current "infodemic" age, findings from this study should have much to contribute to the future development of information management theories. We encourage future research to look into this possibility.

5.5. Limitations

Limitations of the current data need to be considered. First, due to strict regulations during the pandemic, sampling for this study was not probability-based. We noticed that the ratios of female and higher education participants were relatively high in this study, potentially a result of selection bias. Second, all data collected in this study were self-reported. In particular, the measures of information quality and frequency of exposure were based on individual assessments and may contain bias. Third, the surge and non-surge areas examined in this study have important socio-economic differences. Although we controlled for a number of socio-economic factors in the main analyses, our results may still be confounded by unobserved differences between the two regions. Finally, the current data are cross-sectional, thus unable to speak to the causal order of the observed relationships.

6. Conclusion

This study examined the public's ability to identify COVID vaccine misinformation in two provinces in China, and investigated the relationships between such ability and a range of sociodemographic, information, and geographic risk variables. We found that trust in information sources was a strong predictor of the public's ability to identify misinformation and the nature of this relationship varied between official and informal information sources. We also found that perceived information quality mattered in misinformation identification and certain population segments were at greater risk of being misled by false COVID vaccine information. These findings provide useful insights for the continued efforts to promote COVID-19 and other vaccinations in China.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the institutional review board of the Social Science, Jinan University. The studies were conducted in accordance with the local legislation and institutional requirements. The ethics committee/institutional review board waived the requirement of written informed consent for participation from the participants or the participants' legal guardians/next of kin because the survey was conducted online during the pandemic and could not provide written informed consent.

Author contributions

JL: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing – original draft, Writing – review & editing. YC: Formal analysis, Investigation, Project administration, Writing – original draft. XZ: Formal analysis, Methodology, Supervision, Writing – original draft, Writing – review & editing. XY: Data curation, Formal analysis, Project administration, Writing – original draft. FW: Writing – review & editing, Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Navigating misinformation and political polarization of COVID-19: interviews with Milwaukee, Wisconsin county public health officials

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Introduction: The spread of misinformation combined with the political polarization of the COVID-19 vaccine created major challenges for public health officials responding to the COVID pandemic and vaccine roll-out. The challenges public health officials faced when making safety recommendations and promoting the vaccine only exacerbated the already exhausting work conditions they experienced since the start of the pandemic. Combating misinformation while receiving inadequate political support led to burnout for many public health officials. As such, they had to adapt and develop new strategies for increasing vaccine acceptance and decreasing vaccine hesitancies.

Method: This study was conducted through qualitative interviews with seven Milwaukee County public health officials. This study aimed to determine how public health officials perceived misinformation and political polarization during the pandemic. Additionally, the study aimed to learn more about strategies county health officials used to combat misinformation while increasing vaccine uptake in their communities.

Results: Thematic analysis of the interviews identified three major challenges faced by public health officials in promoting vaccination: dissemination of misinformation in media, political polarization of COVID and its contribution to vaccine acceptance and COVID fatigue, and assessment of the risks associated with disease severity versus vaccine safety considering limited public health resources.

Discussion: Learning from public health officials allows us to better understand their perceptions of the extent of local vaccine hesitancies and their advice on how to counteract fears and misinformation and to promote COVID vaccine uptake. Political polarization of COVID and misinformation affected community vaccine acceptance and challenged local public health leadership.

KEYWORDS

COVID-19, vaccine, public health leadership, political polarization, public health burnout, risk severity, COVID-19 misinformation

Introduction

The COVID vaccine has been proven to be safe and effective through rigorous efficacy trials. Vaccine effectiveness monitoring found the odds of hospitalization fell by about 70% after one or two doses, the chances of severe disease (having five or more symptoms in the first week of illness) dropped by about one-third, and the likelihood of having long COVID (symptoms for at least 28 days after infection) was halved (1). The addition of COVID boosters has increased overall vaccine effectiveness in protection against infection to nearly 70% among adults and 94% effectiveness in preventing death (2). However, despite considerable evidence of safety and effectiveness, vaccine uptake has been suboptimal.

Literature review about misinformation

COVID-19 vaccine

Vaccine safety is a consistent concern for many people and can be a primary factor in their hesitancy to receive the vaccine. Research has found that people who believe vaccines are unsafe are less willing to receive them, know less about the infection, and are more likely to believe misinformation about the vaccine (3). Additionally, research findings suggest that those who believe the COVID vaccine to be unsafe have lower levels of health literacy, less formal education, lower income, and are more likely to live in rural areas than people who believe the vaccine is safe (4). In Milwaukee County, 90% of residents aged 25 and over have a high school diploma or higher, while only 32% have a bachelor's degree or higher (5).

Research suggests that communities of color tend to have low vaccine confidence and high vaccine hesitancy (6, 7). For historically marginalized groups, such as African Americans, their history of oppression when seeking adequate healthcare, and persistence of significant health disparities in the present, make it even more challenging to overcome hesitancy for a new vaccine, like the one for COVID (6, 7). Research suggests vaccine acceptance can be increased and uncertainty reduced more effectively through vaccine interventions, whereas removing the choice through a mandate may negatively impact vaccine acceptance (8).

The COVID vaccine has been met with much pushback and hesitancy since its initial roll-out. As of February 2023, 62% of Milwaukee County residents have completed the primary COVID vaccine series, well below the United States average of 69% (9, 10). Vaccination rates are highest among people above age 65, females and Asians and lowest among youth, men, black individuals, and Hispanics (10). Of all Milwaukee County residents, only 15% of the population have received the bivalent booster as of February 2023 (10). Only 17% of Wisconsin residents received the current COVID booster, roughly the same as the 16% US average (2, 9). These low rates of vaccine uptake could result in a resurgence of COVID cases, hospitalizations, and deaths. It is essential to increase vaccinations and boosters. Evidence suggests the leading way to increase vaccine acceptance and uptake is through intervention projects that reduce vaccine hesitancies and promote accurate information by boosting confidence in the safety and effectiveness of the COVID vaccines, combating complacency about the pandemic, and increasing the convenience of getting vaccinated (11).

Media

Research findings indicate people have concerns about side effects and safety of the COVID vaccine, lack trust in the government, and are concerned that COVID vaccines were developed too quickly (12). However, unlike past vaccines, the decision to receive the COVID vaccine is also heavily affected by cultural norms, social and peer influences, and political views (6). Distrust of the government and health care systems has contributed to COVID vaccine hesitancies for many Americans (6). Opposition to the COVID vaccine by media outlets, political polarization of COVID, and the spread of misinformation has further reduced vaccine acceptance, especially in lower-income areas of the US (7).

Political polarization

The bi-partisan structuring of the US is believed to have contributed to political polarization of the COVID pandemic as people received information from polarizing, biased informational sources while having decreased cross-partisan social interactions and information sharing (13). Much of public health response during the pandemic, including safety recommendations, social distancing, mask wearing, and vaccine promotion, was disseminated through various media outlets. US media sources with differing political alignments portrayed COVID differently; certain politically charged media sources reported more negatively about COVID and recommendations made by health authorities (13). Throughout the pandemic, decision making authority was questioned as political parties were divided on how to respond to the pandemic while considering how the US economy would be affected, further influencing the polarization of public opinion (14). More research is needed to better understand how political polarization can be mitigated so that it does not affect public opinion to the degree it has throughout the COVID pandemic.

Public health leadership

COVID fatigue is a growing problem for the general population and the healthcare system as the pandemic lingers. A COVID-fatigued population in combination with health care provider burnout has exacerbated an already stressed health care system. Since 2020, 1 in 5 healthcare workers have quit their jobs, and over 50% of those who quit cited the COVID pandemic and burnout from work as main reasons (15). Burnout among healthcare providers increased as COVID related hospitalizations increased, many of which could have been prevented by increasing COVID vaccination rates, especially with the bivalent booster. More specifically, public health workers, compared to healthcare providers, saw even greater levels of burnout during the pandemic, accompanied with reports of exhaustion, anxiety, and depression (16). Over two-thirds of public health officials have reported experiencing increased burnout, many of whom also

reported experiences of professional abuse, harassment, and personal threats which negatively impacted their jobs, further increasing burnout (16, 17). For many public health workers, the burnout, harassment, stress, and depression stemming from the pandemic proved to be too much which has led to the resignation of hundreds of US public health officials since 2020 (17). Further research is needed to better understand why public health officials experienced such high levels of burnout, what was done to alleviate that burnout, and additional negative impacts they experienced while performing their duties to serve and protect their communities.

Study objectives

Factors affecting vaccine acceptance among Milwaukee County residents during the initial roll-out of the COVID-19 vaccine challenged public health officials who responded with new strategies. Public health officials provided their observations and experiences of factors that influence community beliefs about health interventions. Study findings can be used to counteract misinformation and to support public health officials during the next public health crisis. This study provides new insight, and a better understanding of how public health officials were constantly challenged by rapid, vast dissemination of misinformation and unsupported by decision makers. The challenges health officials faced led them to feel overwhelmingly burned-out and that they were no longer trusted as a key source for COVID prevention and safety information. The purpose of this study was to answer two major research questions using public health interviews:

1 How did misinformation and political polarization of COVID and the COVID-19 vaccine affect how Milwaukee County public health officials performed their duties and responsibilities during the pandemic?
2 What COVID vaccine confidence boosting strategies were used in Milwaukee County and what additional strategies were used by public health officials to counter misinformation and increase vaccine uptake among the different communities in Milwaukee County?

Methods

Study setting

Milwaukee County is one of the most racially and economically diverse and segregated counties in Wisconsin; it is home to approximately 920,000 adults with 28% Black or African American, 16% Hispanic/Latinx, 5% Asian, 1% American Indian and Alaskan Native, and 50% White/Non-Hispanic in 2022 (5). Low income and poverty are challenges faced by many Milwaukee County residents. The percent of persons in poverty in Milwaukee County (18%) is almost double the whole state of Wisconsin and the median household income is $55,000, compared to $67,000 for the state (US Census, 2021). Almost 10% of residents do not have health insurance, compared to almost 7% for the whole state (US Census, 2021).

Study design

The study was performed using an exploratory approach through qualitative interviews with seven public health officials in Milwaukee County. An explanatory design allowed for construction of interview questions that would obtain in depth and diverse responses from public health officials (18). No one health official's response to a question was the same as another's responses. Interviews with local public health officials allowed an analysis of unanticipated comments and to better understand responses in real-time, allowing the interviewer to ask additional follow-up questions (19). Interview questions were guided by findings from our literature review, the specific aims of the study, and the results of focus group interviews with Milwaukee County residents regarding COVID risks that were conducted earlier in the study (20). Interview questions asked about the vaccine trends public health officials witnessed, factors they noticed contributing to vaccine acceptance in their communities, vaccine promotion ideas, and interventions that they conducted to increase vaccinations among at risk and hesitant populations. Participants were provided the interview guide in advance so that they could prepare accordingly and share as much information as possible. Participants were given the opportunity to email study staff with any questions regarding the interview or study protocol.

Recruitment

Our goal was to establish a heterogeneous group of public health officials from various jurisdictions of Milwaukee County. The principal investigator emailed Milwaukee County local health department leaders to recruit them to the study. The Medical College of Wisconsin Human Rights Review Board reviewed and approved all study activities. Participants were sent an informed consent informational letter prior to the interview. Participants verbally provided informed consent upon their involvement in this study and were informed of additional research outcomes that may stem from their participation. Seven public health professionals were interviewed between March 30 and May 18, 2022. Five were women, two men. Their educational credentials included MPH (4), MS, MA, RN, and MD. Their titles included health officer (5), director (2), and nursing supervisor. They worked at city health departments (6) or a county health department.

Data collection

Interviews were conducted by Zoom and lasted approximately 30–45 min each. Interviews were professionally transcribed verbatim and deidentified for analysis.

Interview protocols

Public health officials responded to interview questions addressing three different survey constructs: social media activity, COVID and perception of risk, and public health employee burnout. An example of each construct is listed below. The interviewer addressed each area

as thoroughly as possible in the 30–45-min span allotted for the interviews. Public health officials were open with their responses and provided detailed responses to each question and any follow-up questions.

- Social media activity: What forms of media, do you think, have been accurately communicating 'the facts' to the public? (e.g., specific TV, print news, radio/podcasts).
- COVID and perceptions and risk: Do you have any concerns about COVID vaccines, or the way in which they are being used? (e.g., use in adults vs. use in children). How can those concerns be reduced?
- Public health employee burnout: What are some of the reasons you have noticed that have led to public health officials transitioning out of their field?

Data analysis

An inductive analysis approach was used which included open coding, creation of categories, and abstraction (21). Our research team read the transcribed interviews multiple times to understand the shared information. A coding tree was created to capture specific terms or phrases using an inductive coding approach in which codes were generated as the transcribed interviews were read and analyzed. Once all text segments were coded, we then created categories and further synthesized into themes. Meaning was given to codes through the categorization process. For instance, specific codes were assigned to text segments that mentioned vaccine hesitancies, vaccination strategies, vaccine misinformation, etc., but these coded segments were all then categorized as "Contributing factors for vaccination." Intersecting codes and coded segments were identified which allowed for the recognition of relationships and theme development. Direct quotes and phrases from public health officials were analyzed for further meaning which led to the generation of possible themes, as part of the contextualization process. Themes were further developed through abstraction, using reoccurring codes and contextualizing quotes from interview participants. MAXQDA software was used for coding and generating reports with coded segments and quotes to be used for analysis. Noteworthy text segments were highlighted and used to support the credibility of our themes. Quotes were selected to be included in the results section to follow. Descriptions were developed from the reoccurring themes which provided further context to further support the created themes discussed throughout the results.

Results

Using thematic analysis, we identified the following three core themes: (1) misinformation in the media; (2) the role of political polarization in COVID fatigue; and (3) weighing the risks of COVID severity vs. vaccine resources. Descriptions of communication strategies public health officials used to counter-act misinformation and disseminate accurate information are included in a flowchart at the conclusion of the results (Figure 1). The flowchart additionally includes challenges public health officials had to persevere as they fulfilled their duties and responsibilities during the pandemic.

Misinformation in the media

When asked about how the population they served learned of the COVID pandemic and vaccine rollout updates, public health officials responded that they received information from various news outlets including television, radio, internet websites, and social media. Different media outlets delivered their messages in different ways and not all messages contained accurate information. Participants reported that it was difficult to monitor news delivered through social media for accuracy.

There were multiple instances where myths and facts regarding the COVID vaccine were mixed. All participants reported how social media allows for the dissemination of misinformation. One stated:

> *"I think one of the themes throughout the pandemic given how politicized, for better or worse, that the topic of COVID became, was really coming to the reality that social media in particular is a platform that can promote misinformation, disinformation, or accurate information."*

Another noted how they *"felt and experienced the platform of social media providing both disinformation and misinformation."*

Multiple health officials mentioned vaccine safety was a concern among adult community members, even noting rumors circulating about the vaccine being unsafe or that it contained "trackers":

> *"When the vaccine became available, especially early on, we had quite a few questions about the safety, rumors about trackers or those things are in vaccines."*

One participant noted they came across a social media post saying, *"Vaccines Kill"* followed by a several comments with some people in agreement. Social media was not the only source of COVID misinformation. Participants also mentioned that community members received information from radio or television news programs addressing the COVID vaccine in negative ways and that these sources also sometimes disseminated false claims about the vaccine and severity of COVID. With so many sources of information available to community members, health officials took on the responsibility to monitor the public's perception of the COVID vaccine.

Misinformation about disease severity and mortality caused people to question their need to be vaccinated. Another health official mentioned they had community members denying that deaths attributed to COVID were caused by COVID, claiming that the deaths were caused by other factors:

> *"They were saying that we are exaggerating the seriousness of COVID, or the impact that it's having on some individuals, or the number of individuals that are dying. Thinking that the death data is being exaggerated or the – you know, we have those conversations with some stories, 'Oh, they died in a car accident, but they had COVID, so you said they died of COVID'."*

Claims that COVID mortality rates were much lower than those officially reported were common in those communities. No evidence was provided to support these claims, but they circulated, nonetheless.

Combatting misinformation is a challenge in the public health sector and necessary for increasing COVID vaccine acceptance. When

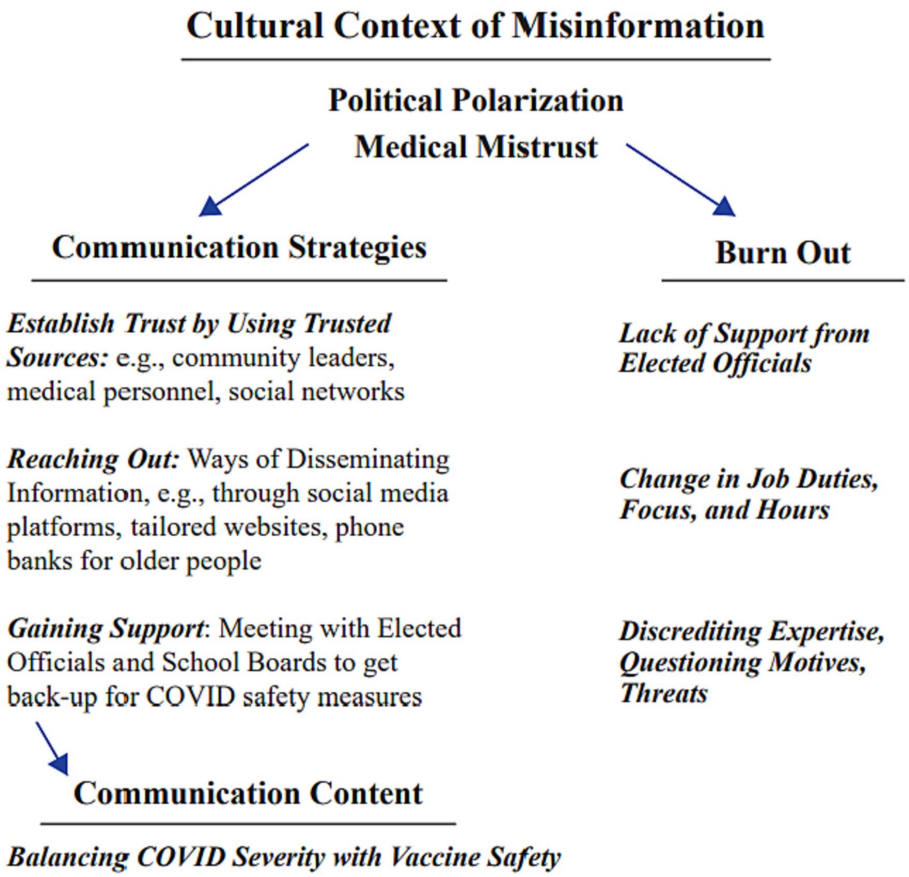

FIGURE 1
Strategies used by public health officials to navigate the effects of misinformation, medical mistrusts, and political polarization during the pandemic are included in the flow chart above to the left. The resulting challenges health officials faced (burnout) during the pandemic are included on the right. Together the two columns depict the continuous efforts public health officials made while serving their communities throughout the pandemic.

asked how they responded to misinformation while increasing accurate information, our health officials provided several different strategies, such as working to obtain community leader support for their decision making on COVID recommendations and empowering grassroots community movements. When investigating strategies to connect with community members, one health official noted:

> *"As we look over the span of the pandemic to date, we really just want to recognize when we empowered grassroots community neighborhood members to amplify messages on their own social media platforms, Facebook, TikTok, you name it, whatever, that is where we really were seeing some of the most direct influence to some of the most vulnerable populations and had the best sort of reach."*

Multiple public health officials noted the importance of connecting with their community members during the complicated times of the pandemic, the continued use of grassroot campaigns when developing effective messaging, and the collective efforts of public health and community centers when promoting accurate information. These public health officials took charge and noted how it was their responsibility to disseminate accurate information to their communities. One health official explained their unbranded, custom designed strategy for promoting truth about COVID information and testing through development of a dedicated, COVID informational website to be used by all community health organizations and unrestricted by a sole health entity:

> *"As the pandemic marched forward and time passed, that then got converted into healthy MKE. And so our kind of constant narrative was, "Come here for a source of truth about all things COVID." And so that platform was created, again, with input from grassroots community members who were very clear about naming, "I want to see people from my neighborhood, who look like me, who are from my neighborhood and look like me that are behind the photographs that are on the websites. Who's behind the camera matters, who's on the webpage matters." I think what was really exceptional about the work that we continue to do, it's not branded. So, all of the health systems, all of the community health centers, other partners, contribute and used this. And we were able to, collectively, in the absence of a brand come together and say, "This will be our source of truth, to help streamline some of the narrative."*

Another public health official mentioned how they tried to establish networks throughout their community so their decision-making regarding COVID safety recommendations would be supported:

> *"With our schools, with our elected officials here, with our common council, and our mayor, and our administration. Spending time at those meetings, sending regular updates, often by email earlier in the pandemic, or having phone calls with them to answer their questions and help them understand. Also, a lot of messaging to different groups of businesses. So, you know, to churches, to childcare centers, to restaurants and bars, other businesses. So, really trying to send specific information that relates to those businesses or organizations as they were making decisions."*

Several participants also noted using social media platforms to disperse accurate information and vaccine updates. Health officials had to adapt with the times and navigate social media usage and messages to the point where they had to "outcompete" possible sources of misinformation:

> *"I think I would say we have a couple of our social media posts that you know kind of were shared widely, went viral, whatever you want to say. So, I do think that when we took the time to kind of make a higher quality graphic that would illustrate, whether it was data or mitigation strategy that we were recommending. I think that that was probably more of the most effective, just given the number of people who viewed it and shared it."*

One public health department implemented a state funded survey that they disseminated to their community addressing health equity and barriers to vaccination with a focus on vaccine effectiveness and safety. They obtained over 500 responses. The survey participants had mixed opinions when asked what their trusted sources of COVID related information are. Some survey participants indicated public health and government officials as trusted sources, while other participants noted public health and government were not their first source for information, listing family and friends above government. The health department used results from the surveys, specifically the age range for participants who did note they use government and public health as sources of information, to tailor social media messaging and platforms. The tailored messages were perceived to be more useful for the targeted audience, residents in their 30s and 40s for the most part, who see the health department as a reliable source of information. Notably, the area this organization served had very high COVID vaccination rates.

Establishing trustworthy connections within the community was also recognized as a useful strategy for public health officials when addressing individuals' concerns about the vaccine:

> *"We realized the one-on-one support was much more likely to lead to somebody then getting the vaccine if they were able to talk to a nurse or talk to somebody and answer those questions by somebody they trust, that was actually a medical person."*

One health official noted *"using CDC and DHS wording"* when recommending vaccines to their community members. Multiple participants stressed contacting older community members who may not have social media via phone calls or implementing "hotlines" (a 24/7 number that community members could call to ask vaccine related questions) to provide any vaccine updates and recommendations. Aforementioned strategies used by public health officials to navigate misinformation and promote accurate information are displayed in Figure 1 below. Ultimately their takeaways for effective strategies were developing vaccine intervention plans in different languages and tailored for different cultural groups and the re-direction and correction of misinformation public health officials came across on social media while trying to not be dragged into an argument or project any negativity.

Political polarization and burnout

Effective vaccine roll-out was dependent upon politicians and public health officials working together to develop a vaccine dissemination plan that would boost local vaccine acceptance. However, with the vaccine being rolled-out during the conclusion of an election year in the US, health departments began receiving backlash and negativity as it became a hot topic in the political forum with continued lower acceptance by the Republican Party versus the Democratic Party (22). Overt politicization of the public health response, including widespread misinformation related to COVID vaccination, was spread by various forms of media and politicians (11). The public health officials interviewed through our study reflected on the high degree of opposition to the COVID vaccine leading up to and during the roll-out. The lack of political support for public health officials exacerbated already exhausting jobs. One health official detailed their need for support in their decision making from political or administrative leaders, while trying not to politicize the vaccine:

> *"So, having leaders of the community also express their support, I think was impactful, for sure. And we have seen that for other type of public health responses as well. But honestly, though, it was a little bit harder for something like this because people did not really want to always get involved in something that's controversial. Like, you know, "I support it, but I'm not gonna be public in supporting it." I think that also got to be a challenge because it was so politicized."*

With a country divided politically at the end of 2020, post-election, many Americans held fast to their beliefs. Participants in our study explained how more conservative media sources displayed more opposition to the vaccine than liberal media sources; thus, the more conservative community members who relied on those resources had more opposition to the vaccine. News outlets tend to be a source of information for many people; however, news stations do not always present a situation or event in the same way spreading contradictory information on a topic. FOX News and MSNBC, media sources traditionally on opposite ends of the political spectrum, were even discussed during one interview as being information resources for certain community members, creating further challenges for health officials attempting to combat misinformation.

> *"Fox News was probably giving a much different spin than MSNBC on a variety of topics. And so, I would say the place where that information originates, whether it's with a local health department, a state health department, is probably more important than what channel it was on or what source of information was out there. It was very interesting to see all of the negative sources of information and disinformation or misinformation that came out."*

Participants revealed how some community members and political leaders were in support of the vaccine, while others tended to downplay the severity of the pandemic and the need for a vaccine. One public health official explained their frustration by describing how their small team worked to provide services to their community while receiving pushback from "leaders":

> *"Eleven of us are working together in a very small geographic area with very fluid borders and irregular borders – being on the same page, supporting each other, providing prospective and experiences is gonna be very, very important. But that's what we can do. I cannot change the political leaders in the village next door to me that basically chastised the health officer in an open public forum and said that what they are doing is unnecessary and inappropriate."*

One public health official went so far as to say that vaccines were politicized to such a degree that for a Republican, getting vaccinated was tantamount to switching political loyalties.

> *"I do not think in the history of public health have we ever, ever predicted something would be so politicized to this level, where it wasn't really about really health, it was more political lines. You're betraying a certain thing if you were doing it, to be honest, that was a lot of it."*

Politicization of COVID not only affected vaccine acceptance, but also the day-to-day work of public health officials creating an already stressful work-life. Burnout due to COVID was encountered by all the public health officials involved in this study as they and their co-workers worked long hours, changed roles in the workplace frequently as co-workers retired or quit, and delivered difficult and important messages, recommendations, and restrictions to their communities. They fulfilled many different tasks and roles while receiving backlash from groups who opposed their guidance and working with a political system that sometimes failed to support them. When we asked our participating public health officials what exacerbated their feelings of burnout, they had many different responses, and all participants noted a lack of full support by a political system that they felt should be doing the most to unite and protect people:

> *"We run up against a situation where politicians, political leaders, school leaders have pulled away mask mandates and mask guidance or even mask recommendations."*

The same health official also discussed how the lack of support created additional burnout during an already overwhelming experience:

> *"People got dramatically burned out. They got frustrated with the political process. They got frustrated with the community members who continue to chastise them on social media, print media, at public meetings. Discouraging or discrediting their expertise."*

A second health official also noted the challenges politics created as they strived to fulfill their responsibilities and duties:

> *"We've become a sort of lightning rod for threatening people's freedoms and having a negative impact on the economy, when, in fact, all we were trying to do was save people's lives. Like, at the end of the day that's all any of us wanted to do but because of the politics related to the pandemic it's become something very different."*

Half of our participants shared how they or their coworkers had been personally attacked on social media or through their organization's website. One health official stated they were sent a post with sheep wearing masks and were accused of committing crimes against humanity while trying to promote the COVID vaccine. Another participant shared how many health officials were threatened by various community members and elected officials while doing their job:

> *"Burnout and exhaustion is probably the theme of it all amongst leaders. We were pretty fortunate here in our community where I can say I do not think our previous health officer and myself ever received death threats. I did not have to have police positioned outside my home. I did not have to be escorted to my car from board of health meetings or council meetings. But a lot of my peers did."*

Participants explained how they had co-workers experience fatigue and burnout to the extent that they quit their jobs, further exacerbating burnout as workloads of those remaining increased. Some health officials quit due to the arduous nature of the work. Others found it to be a good time to change careers as they were forced to provide guidance and restrictions to people who viewed it negatively. Others had to change from working on a public health task they enjoyed to something they did not enjoy or felt they lacked the experience to do and opted out of the position as a result. While factors contributing to burnout varied for our public health officials; all health officials reported some level of burnout. A summary of challenges contributing to public health official burnout is included in Figure 1.

Weight of COVID severity versus vaccine resources

Public health officials tried to help vaccine hesitant community members to weigh more appropriately the risks associated with the COVID vaccine with the risks of contracting COVID while health officials had to consider their own resource depth. Five public health officials reported that they encountered community members who were not concerned about contracting COVID because they perceived that they were at low risk for illness or minimized its severity. The severity of COVID proved to be a topic of debate along with the safety and effectiveness of the vaccine. One public health official explained how they had to weigh their limited resources and time when developing vaccine promotion messages. For some age groups, such as 65 and older, COVID complications can be more severe than in younger age groups. Additionally, parents who are already hesitant about childhood immunizations and fatigued from all the COVID information circulating already may be less receptive to public health messaging. Weighing resources for chronically underfunded public health organizations forced public health officials to make some difficult decisions. When deciding on how to use resources, health officials must address who can benefit most from public health messaging:

> *"We're weighing the risks and the benefits of continuing to talk about COVID vaccines specifically when we have seen such a decline in routine childhood immunizations. What are the risks and the benefits of folding COVID into that, or attaching it into that messaging?"*

Participants found promoting the COVID vaccine for children even more challenging, especially those with anti-vaccine parents. Children often have mild symptoms and parents assessed the vaccine as being a greater risk than COVID illness. While complications from the vaccine are extremely rare, they are not zero. One health official mentioned the risk of myocarditis in adolescent boys who received the vaccine. When this participant was asked if they had any concerns regarding the safety of the vaccine, their response was:

> "*I mean, as far as safety of vaccines, no. Not really. I mean, the main risk that can come is myocarditis. Is there a small risk of myocarditis in adolescent boys? Yes. When you have that risk benefit discussion, if you actually look at the numbers, and there's a lot of great visualizations of the numbers, it's not even a comparison. The risk, if you get COVID, you are many more times likely to get myocarditis, and so you are preventing that. It's kinda of like, is there a risk of wearing a seatbelt? Yeah. I see people in the emergency department with broken ribs from a seatbelt, or liver injuries from a seatbelt, but for every one of those I see 1,000 more that these lives were saved by a seatbelt.*"

To overcome child vaccine hesitancy, participants explained how children can expose family members or friends who are at higher risk for severe complications from COVID. Just because youths may not be as likely to develop severe complications from COVID, that does not mean they are any less likely to spread the virus to more vulnerable population if unvaccinated. It became evident for our health officials that everyone who can be vaccinated should have the chance to receive the vaccine. One health official even admitted they were unsure of the safety and effectiveness of the vaccine when it was initially rolled out, but they continuously saw the COVID death reports and hospitalizations statistics, so they trusted in science and promoted the vaccine. The challenges health officials encountered while weighing resources when promoting the vaccine among groups when vaccine safety concerns are included as the final branch in the flowchart below (Figure 1). This public health official referred to the vaccine as a gamble but viewed the long-term effects of COVID and the ability to contract COVID more than once as being a greater risk than the vaccine. With the vaccine being created at record speed and its safety being a topic of debate, public health officials had to strategically emphasize how the risks associated with the complications of COVID, ability to contract COVID multiple times, transmitting the virus to high risk loved ones, and the unknown long-term effects of COVID outweighed the risks associated with the COVID vaccine.

Discussion

Effects of political polarization

This study investigated how Milwaukee County public health officials navigated political polarization of the COVID vaccine and misinformation in their communities. We identified three themes constructed from recurring observations and strategies. Factors similar to those found to influence vaccine uptake were mentioned in our participants' responses with particular emphasis on misinformation and political polarization of the vaccine creating challenges for promoting the vaccine in their communities. Rapid, vast dissemination of misinformation in media, political polarization of COVID and the vaccine, and risk assessment of disease severity vs. vaccine safety have received research attention as barriers to vaccination for COVID at both a collective and individual level. Research suggests populations across the world who believe misinformation about the vaccine and severity of COVID have increased vaccine hesitancy; for instance, voters affiliated with the Republican Party have higher rates of vaccine hesitancy than Democrats (22). Effects from political decisions regarding COVID prevention measures can be seen across the different states. States with Republican leadership saw fewer adoptions of COVID prevention recommendations with more delays and increased mortality across races than states with Democratic leadership (23). Wisconsin is one of the most divided states in the nation as noted by its election results. Milwaukee County is not quite as divided as the state with two-thirds of voters in favor of the Democratic presidential candidate, but when voting for their congressional representative, two-thirds of votes were for the Republican candidate (24).

Combatting misinformation

Social media is used more than ever for disseminating news; however, it can lead to rapid spread of misinformation and lead to increasing vaccine hesitancy among communities (11, 25). This study provides evidence to suggest public health officials felt they were not trusted and lacked support when enacting pandemic prevention guidelines and promoting the COVID vaccine. The abundance of contradictory and misinformative messages, often through social media, challenged the actions of our public health officials making it more difficult for them to protect their communities from COVID. The high volume and reach of misinformative posts on social media networks has been explored through various studies (26). Public health officials described the different strategies they used to navigate the challenges that they faced when promoting the vaccine and safety recommendations all while struggling with increasing burnout and high employee turnover. Our public health officials faced a combination of challenges when trying to weigh their resources while attempting to promote the COVID vaccine. The limited supply of the COVID vaccine early-on during the pandemic, in combination with the limited personnel and funds of health departments made for difficult decisions when promoting the vaccine among certain populations who were considered to be less at risk for severe COVID complications who could still contract and spread COVID. These individuals were found to be less likely to accept the vaccine according to our health officials, which may have been due to the early on promotion of the vaccine for more at-risk groups. This helped create a false sense of security for less at-risk groups as they may have felt they did not need to be vaccinated. Once the US had a stable supply of the vaccine, the challenges for promoting the vaccine among less at-risk groups only grew. COVID fatigue began to set in for many people and some of those who had abstained from being vaccinated

as they felt they did not need it as much as other more at-risk people, had no desire to receive it after it became available to everyone. Efforts to vaccinate everyone are still underway, but as more people weigh the decision to vaccinate and health departments are forced to weigh their resources, the trajectory for future booster vaccination coverage is ambiguous. It is important we learn from the early-on COVID vaccine promotion strategies and enforce the need for a highly vaccinated population to keep a virus from spreading and evolving.

Application of theory

Findings from this study can be used to guide interventions to promote vaccine uptake. Future research is needed to understand the perspectives of vaccine-hesitant individuals to learn more about the beliefs that drive the decision to vaccinate or not. Misconceptions and a general lack of trust in vaccines can be assessed, accounted for, and evaluated by using health communication strategies, such as the Health Belief Model (27). The Health Belief Model (HBM) serves as the framework for many public health campaigns. The HBM uses six constructs to predict health behavior: risk susceptibility, risk severity, benefits to action, barriers to action, self-efficacy, and cues to action (28). Components of this theory were intertwined in the vaccine promotion strategies our public health officials used as they focused on disseminating accurate information about the severity of COVID complications, often underestimated by the public, and the benefits of vaccination. The Theory of Planned Behavior (TPB) is the theoretical framework for the investigation of the influences on a person's decision to vaccinate as it allows us to better understand why something or someone else affects a person's decision making. The TPB states that behavioral intention is determined by more positive attitudes toward the behavior, approval of significant others for the behavior (subjective norms), and a sense of personal control over the behavior (perceived behavioral control) (29). Public health officials reported how they believed the rapid circulation of misinformation and political polarization of COVID influenced individuals' decisions to vaccinate. Strategies they implemented had to overcome these influences by targeting components of TPB. Public health officials incorporated TPB and targeted negative influences by developing grassroot campaigns, promoting community leadership and empowerment as they found community members were just as heavily influenced, if not more so by those around them in their own community who had their best interests in mind. Public health officials were not trusted and supported as well as they should have been due to the controversial, politically polarized misinformation regarding COVID circulating through communities who believed misinformation from sources they found to be more trusted or favorable than accurately informative public health officials.

Vaccine promotion recommendations

Health officials had to develop new plans to promote COVID safety recommendations and awareness among the public, all while counteracting circulating misinformation and politically polarizing media sources. To do this, many public health organizations turned to social media platforms. Research suggests social media campaigns can successfully inform the public on accurate COVID information to increase public awareness and education so that behavioral change can occur (30). Social media became a frontier for COVID information dissemination requiring health officials to learn more about effective social media campaign strategies and navigation of various social media platforms that they may have had little experience with prior to the pandemic. To combat misinformation spreading through communities who may not have viewed public health departments as the primary source of COVID prevention information, several public health officials enacted grassroots campaigns and tailored social media messages to increase vaccine acceptance and reduce misinformation that might be causing vaccine hesitancies. The public health officials created their strategies knowing that individuals were more perceptive to messages delivered by people they trust. The Theory of Planned Behavior also suggests that mass dissemination of accurate information can be more effective when tailored for a specific audience who will then reshare the information, as seen with multiple social media platforms used by public health officials.

Future implications

The climate of public health changed drastically once the pandemic began, but it also brought forth long standing issues about how the public health system is supported. Public health officials faced extreme challenges as a divided political system failed to properly fund health departments and support their evidence-based guidelines, restrictions, and recommendations (31). Even prior to 2019, governing parties had not properly supported public health systems in the US. The pandemic proved just how chronically underfunded and underserved the public health system was. Since 2008, the public health workforce has decreased by over 20% while 62% of local health departments have had no increases in funding (32). During the pandemic, public health officials across the nation, including several of our interview participants, were forced to change their roles and/or responsibilities to help with pandemic prevention, monitoring, and mitigation. Officials who had no experience with emerging infectious disease projects had to stop working on their projects to help with pandemic related projects. Opioid abuse prevention, blood lead investigations, health inspections, and countless other projects were halted as health departments did not have the funding or staff to keep up with the COVID response and these other areas at the same time (32). Health departments did not fare well when employees had to switch from their preferred projects to work on COVID related projects. Many of the health officials in our study noted how the reorganization of their department and changing of roles led to the resignation of many public health officials. The strenuous conditions public health officials faced began long before the pandemic. Moving forward, it is essential that our nation focuses on developing, funding, and supporting our public health system. Public health officials are experts in their field. Their expertise should be recognized and supported by political and administrative leaders who make decisions regarding mandates and guidelines created to better protect the health of public.

Additionally, the concerns expressed by public health officials regarding burnout and lack of support should be used to improve the emergency preparedness system in Milwaukee County and perhaps in other communities. This study found many public health officials were overwhelmed from the start of the pandemic, highlighting the lack of

experienced personnel, support from the political system and administrative organizations, and communication with decision making entities. Experts predict future disease outbreaks will occur, and another pandemic is imminent. If another were to occur, it is essential we learn from the past 3 years by providing more support to our public health system, so they can better serve and protect members of the community without the backlash they faced during the COVID pandemic.

Limitations

This study could have benefited from asking public health officials additional interview questions addressing what theoretical models (if any) they used in crafting their messages, such as, using concepts from the Health Belief Model to understand vaccine decision making of community members. We were able to draw inferences from the interview results, but more precise questions would lead to more precise conclusions. Moving forward this study could expand outside of Milwaukee County to the greater Wisconsin area, adding more public health officials to our study who can provide insight into perhaps more conservative counties of Wisconsin.

Conclusions and implications

Through interviews with seven Milwaukee County public health officials and qualitative, thematic analysis, this study successfully identified factors contributing to COVID vaccine acceptance in Milwaukee County, factors affecting public health decision making during the pandemic, and the strategies public health officials used to promote the vaccine and enforce COVID safety precautions. Misinformation in the media, political polarization of COVID and its contribution to burnout among public health workers, and the weighing of COVID severity versus limited vaccine promotion resources created challenges for public health officials in Milwaukee throughout the pandemic. Public health officials guided much of the COVID pandemic response and the initial vaccine rollout. Many times, they received little support from political leaders as the vaccine became politically polarized and they were required to develop strategies to overcome an array of circulating myths and misinformation about the vaccine. By implementing tailored responses to the challenges that they faced, public health officials were able to create strategies for increasing vaccine acceptance and reducing hesitancies. Moving forward, public health officials need the support of all leaders (political, administrative, and community) to be able to best serve their community.

Disclosures

The project was approved by the Medical College of Wisconsin Institutional Review Board.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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Unveiling misinformation on YouTube: examining the content of COVID-19 vaccination misinformation videos in Switzerland

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Social media platforms like YouTube can exacerbate the challenge of ensuring public adherence to health advisories during crises such as the COVID-19 pandemic, primarily due to the spread of misinformation. This study delves into the propagation of antivaccination sentiment on YouTube in Switzerland, examining how different forms of misinformation contribute to this phenomenon. Through content analysis of 450 German- and French-language YouTube videos, we investigated the prevalence and characteristics of completely and partially false information regarding COVID-19 vaccination within the Swiss context. Our findings show that completely false videos were more prevalent, often embedded with conspiracy theories and skepticism toward authorities. Notably, over one-third of the videos featured partially false information that masquerades as scientifically substantiated, associated with higher view counts and greater user engagement. Videos reaching the widest audiences were marked by strategies of commercialization and emotionalization. The study highlights the insidious nature of partially false information in Switzerland and its potential for greater impact due to its seemingly credible presentation. These findings underscore the need for a multifaceted response to misinformation, including enhancing digital literacy among the public, promoting accurate content creation, and fostering collaborations between health authorities and social media platforms to ensure that evidence-based information is prominently featured and accessible. Addressing the subtleties of misinformation is critical for fostering informed public behavior and decision-making during health emergencies.

KEYWORDS

misinformation, COVID-19 vaccination, YouTube, public health, content analysis

Introduction

Since the onset of the COVID-19 pandemic in 2020, a proliferation of (mis)information has been observed globally (Altay et al., 2022), leading the World Health Organization (WHO) to refer to it as an "infodemic.[1]" This misinformation encompasses a wide range of topics, including denial of the pandemic, false symptom control measures (e.g., eating garlic), and conspiracy theories attributing the pandemic to foreign governments or economic elites (AFP et al., 2020; Brennen et al., 2020). Of

1 https://www.who.int/health-topics/infodemic

particular concern is the misinformation related to vaccination, as it can potentially hinder efforts toward vaccination, which is crucial for pandemic containment (Lewandowsky et al., 2021). Furthermore, numerous studies have documented a negative association between belief in COVID-19 misinformation and vaccination intent (Bertin et al., 2020; Roozenbeek et al., 2020; Chadwick et al., 2021; Loomba et al., 2021).

Much of the misinformation disseminated during the first phase of the pandemic was visual and audiovisual content (Knuutila et al., 2020; Vaccari and Chadwick, 2020). Misinformation was mainly spread via social media platforms, such as YouTube and Facebook, or messenger services, such as WhatsApp (Li et al., 2020; Wilson and Wiysonge, 2020). A study showed that 27.5% of the most-viewed YouTube videos on COVID-19 contained misinformation (Li et al., 2020). Moreover, Li et al. (2022) found that ∼11% of YouTube's most-viewed videos on COVID-19 vaccines, accounting for over 18 million views, contradicted the reference standard from the WHO or other public health institutions. YouTube videos by governmental organizations received significantly more dislikes than likes compared to entertainment videos, indicating a less favorable public perception of such content (Li et al., 2022). Although YouTube and social media companies, in collaboration with organizations such as the WHO, have committed to addressing such misinformation, implementation is still difficult and insufficient (Zarocostas, 2020). Despite efforts to combat health misinformation, a substantial portion of highly viewed YouTube content continues to contain misinformation regarding COVID-19 vaccines.

We investigated misinformation on YouTube in Switzerland to expand our understanding of this kind of content and ultimately facilitate its detection and moderation; 61% of the Swiss population regularly used YouTube during the 1st year of the pandemic (Newman et al., 2020), and the Swiss Science Barometer (2020) shows a significant, positive correlation between YouTube use and belief in COVID-19 misinformation. Moreover, it has been argued that online platforms such as YouTube provide new stages for antivaccination groups to spread their messages, expand their reach, and establish new follower networks (Vosoughi et al., 2018; Knuutila et al., 2020). The use of social media in this way is worrying because it can hinder collective action during a health crisis. Misinformed citizens are less likely to take action to mitigate the pandemic or get vaccinated (Allington et al., 2020; Bertin et al., 2020; Roozenbeek et al., 2020; Loomba et al., 2021).

To better understand how producers of misinformation try to deceive YouTube users, we conducted a quantitative content analysis of 450 videos containing misinformation about COVID-19 vaccination. We analyzed different types of misinformation (partially vs. completely false information) and examined views, user reactions, actors, and claims. In addition, we compared videos with an extensive reach to those with fewer views. Finally, we discuss the results considering potential future health crises in which it will likely be essential to detect misinformation early and educate the public about common deception strategies.

Literature review

Misinformation and disinformation dynamics in the public health context

The term "misinformation" is often utilized to denote information that is false or misleading, regardless of the intention behind its dissemination (Tandoc et al., 2018; Wardle, 2018). Distinct from misinformation, "disinformation" represents a subset of misleading information crafted and circulated with the explicit intent to deceive and inflict harm, such as exacerbating social divisions or influencing political decisions (Wardle, 2018). Citizens who accept disinformation as legitimate may base their perceptions and actions on fundamentally erroneous information, leading to significant real-world consequences. Societal challenges are further compounded by what Bennett and Livingston (2018) describe as a "disinformation order," where subcultural frames and false narratives are systematically promoted, often by extreme ideological groups that exploit digital tools such as trolls and bots to broaden their reach (Marwick and Lewis, 2017).

In the contemporary landscape, the COVID-19 pandemic has acted as a catalyst for an unprecedented surge in misinformation, impacting public responses to health directives and fostering a climate of doubt and skepticism (Roozenbeek et al., 2020). The intent behind the dissemination of false information often remains opaque, complicating the task of discerning misinformation from disinformation; therefore, our review adopts a broad perspective, addressing all forms of false information under the term "misinformation" for the purposes of this analysis (Brennen et al., 2020).

Recent literature expands upon the dangers posed by misinformation, highlighting its capacity to shape public attitudes (Loomba et al., 2021; Sharma et al., 2023) and reinforce enduring misbeliefs (Hameleers et al., 2020). These issues become acutely problematic during health crises, where misinformation has been shown to dissuade people from vaccinating, raising individual risk levels and impeding collective efforts to manage the spread of disease (Wilson and Wiysonge, 2020).

The complexities surrounding vaccine safety narratives have been explored in studies like Lockyer et al. (2021), which delve into the qualitative aspects of COVID-19 misinformation and its implications for vaccine hesitancy within specific communities. Exposure to misinformation caused confusion, distress, and mistrust, fueled by safety concerns, negative stories, and personal knowledge. Further Rhodes et al. (2021) examine the intentions behind vaccine acceptance or refusal, illuminating that vaccine acceptance is not static and can be influenced by a variety of factors, including perceptions of risk and the flow of information regarding vaccine safety and necessity.

Conspiracy theories have been identified as a common form of misinformation, particularly in the context of vaccine acceptance. Featherstone et al. (2019) examine the correlation between sources of health information, political ideology, and the susceptibility to conspiratorial beliefs about vaccines, showing that political conservatives and social media users are more susceptible to vaccine conspiracy beliefs. Moreover, Romer and Jamieson (2020)

provide insights into how conspiracy theories have acted as barriers in controlling the spread of COVID-19 in the U.S., a pattern observable in other contexts as well such as the Netherlands (Pummerer et al., 2022).

Finally, emotional appeals play a crucial role in the dissemination and impact of misinformation. Carrasco-Farré (2022) underscores that misinformation often requires less cognitive effort and more heavily relies on emotional appeals compared to reliable information. This tactic can make deceptive content more appealing and persuasive to audiences, particularly in a context like social media where emotional resonance can enhance shareability. Sangalang et al. (2019) further emphasize the potential of narrative strategies in combatting misinformation. They propose that narrative correctives, which incorporate emotion-inducing elements, can be effective in countering the persuasive appeal of misinformation narratives. Additionally, Yeo and McKasy (2021) highlight the role of emotion and humor as potential antidotes to misinformation. Their research suggests that integrating emotional and humorous elements into accurate information can enhance its appeal and effectiveness in counteracting the influence of misleading content. Moreover, emotional appeals in misinformation serve a distinct purpose compared to neutral presentation (Carrasco-Farré, 2022). Emotional content is designed to engage users at a visceral level, tapping into their feelings and biases. This strategy can make misinformation more persuasive and shareable, as emotionally charged content often resonates deeply with users, compelling them to react and share. Such content, leveraging human emotions like fear, anger, or empathy, tends to have a higher potential for viral spread, thereby amplifying its reach and impact (Yu et al., 2022).

This body of research underscores the importance of understanding and strategically utilizing emotional appeals in both the propagation of misinformation and the development of interventions to counteract its influence.

Considering these issues, it becomes evident that misinformation is not a monolithic problem but a multifaceted challenge that intersects with safety, efficacy, and conspiracy theories and is deeply entwined with emotional appeals. Misinformation often leverages emotive narratives to capture attention and elicit reactions, making it more persuasive and shareable among users. The research discussed underscores the need for nuanced approaches to tackle misinformation. These insights are instrumental in devising strategies to counteract misinformation and foster an informed public that can critically engage with health information during health crises.

Misinformation on YouTube

Several authors argue that social media platforms such as YouTube facilitate the spread of misinformation (Li et al., 2022; Tokojima Machado et al., 2022). Users primarily search for entertainment on social media platforms, accidentally come across (false) information, and sometimes spread it carelessly (Boczkowski et al., 2018). Emotional and visual content attracts users' attention, and user reactions (e.g., likes, shares, and comments) increase their visibility due to how the algorithms work (Staender et al., 2021). Misinformation can be found on all major social media platforms, but research suggests that YouTube played a vital role relative to COVID-19. For example, in the United Kingdom, YouTube was the source of information most strongly associated with belief in conspiracy theories: Of those who believed that 5G networks caused COVID-19 symptoms, 60% said that much of their knowledge about the virus came from YouTube (Allington et al., 2020). Li et al. (2022) analyzed 122 highly viewed YouTube videos in English related to COVID-19 vaccination; 10.7% of these videos contained non-factual information, which accounted for 11% of the total viewership. The authors thus posit that the public may perceive information from more reputable sources as less favorable (Li et al., 2022). Furthermore, producers of misinformation often employ rhetorical strategies to enhance the appeal and persuasive power of their content on social media. These tactics include mimicking the style and presentation of reliable sources, using emotional and sensationalist elements to captivate audiences, and exploiting the dynamics of social media algorithms for wider dissemination (Staender et al., 2021).

While emotional content has been identified as a powerful tool in spreading misinformation, it is important to note that a neutral presentation can also enhance the believability of misinformation (Weeks et al., 2023). When misinformation is presented in a neutral, matter-of-fact manner, it may be perceived as more credible and less biased, making it easier for users to accept without skepticism. This subtlety of presentation can make neutral misinformation insidiously effective, as it can blend seamlessly with genuine information, evading immediate doubt or critical scrutiny. Tokojima Machado et al. (2022) found that misinformation producers use tactics to disguise, replicate and disperse content that impair automatic and human content moderation. According to the authors, the analyzed YouTube channels exploited COVID-19 misinformation to promote themselves, benefiting from the attention their content generated. Because of the strategic approaches adopted by content producers to enhance dissemination, YouTube played a significant role in the widespread distribution of misinformation during the pandemic.

Due to this massive spread of misinformation, YouTube revised its moderation policies in April 2020 to make credible content more visible and delete dubious content (YouTube, 2020). However, it took an average of 41 days for content with false information to be removed, so it could still reach many users (Knuutila et al., 2020). Moreover, monitoring misinformation in languages other than English continues to be a significant challenge for YouTube, and its functions must be improved. As Donovan et al. (2021) highlights, content creation models are necessary to identify "superspreader" networks and fight against organized manipulation campaigns.

Hypotheses and research question

Misinformation is disseminated with different goals, and its content can vary considerably (Staender and Humprecht, 2021). For example, half-truths can appear more credible and thus be more convincing than completely false content (Hameleers et al., 2021). Partly false information presents a unique challenge as it often closely resembles the truth. Creating a veneer of verisimilitude that can mislead viewers. This type of

misinformation subtly distorts facts or presents them in misleading contexts, making it difficult for users to discern inaccuracies (Möller and Hameleers, 2019). The proximity of this information to factual content makes it particularly insidious and challenging to counter. Given its resemblance to factual content, partly false information often evades scrutiny and challenges conventional fact-checking approaches. This makes correction efforts more crucial yet more complex, particularly when such content is designed to mimic reputable sources. The need for correction is paramount precisely because these subtleties can lead to widespread acceptance of inaccuracies under the guise of credibility (Hameleers et al., 2021).

Brennen et al. (2020) examined which types of disinformation were generated most often in the United Kingdom during the first phase of the COVID-19 pandemic. The most common types were messages that frequently contained accurate information but were slightly altered or reconfigured. For example, facts were presented in the wrong context or manipulated. However, Brennen et al. (2020) found that over a third of the disinformation studied contained completely fabricated and fake content.

Switzerland has no findings yet of the types of misinformation that were disseminated during the pandemic. In contrast to other democratic countries, Switzerland is more likely to be resilient to misinformation (Humprecht et al., 2020) because of its political and media characteristics (i.e., high level of media trust, lower audience fragmentation and polarization, consensus-oriented political system). Therefore, producers of misinformation may try to mimic news media coverage and refer to actual events or facts to avoid being perceived as misleading. Against this background, we assume that *partially false information about COVID-19 vaccination is more frequent on YouTube than completely false information (H1).*

The challenge in automatically identifying misleading content on YouTube has made it difficult to fully understand the scope and tactics employed in such misinformation. The primary goal of video producers in this context is to maximize visibility, often measured in terms of view counts, thereby ensuring their deceptive messages reach a broad audience. Despite the prevalence of such content, there is still limited research on the specific types of arguments used in these widely viewed misleading videos. Pioneering work by Kata (2010) in analyzing anti-vaccination websites provides some insights. This research explored the nature of misinformation on these platforms, focusing on the themes and narratives employed to counter vaccine advocacy, including discussions on safety and efficacy, alternative medicine, civil liberties, conspiracy theories, and religious or moral objections. Such studies are crucial in shedding light on the strategies used in the dissemination of misinformation, particularly in the context of public health. Although Kata (2010) did not distinguish between types of misinformation, findings from studies on COVID-19 (Skafle et al., 2022) suggest that conspiracy theories and falsehoods about side effects are found primarily in entirely false content. Vaccination misinformation grounded in conspiracy theories frequently claims that corrupt elites run hidden power structures and network with pharmaceutical companies to make money or depopulate the world (Skafle et al., 2022). We therefore postulate that *completely false information contains conspiracy narratives (H2a) more often than partially false information does.* Similarly, we propose that *completely false information contains claims about vaccination's side effects and safety aspects more frequently than partially false information does (H2b).*

Kata (2010) demonstrated that vaccine misinformation frequently employs purported scientific evidence to lend a semblance of credibility to distorted information. This tactic typically involves blending actual scientific facts with fabrications, a characteristic predominantly seen in partially false information (Möller and Hameleers, 2019). Based on this understanding, we hypothesize that *references to scientific evidence are more common in partially false videos than in completely false videos (H2c).*

Research has shown that misinformation is often characterized by antielitism and includes criticisms of elite actors, such as politicians, or, especially in the context of health issues, medical actors (Hameleers, 2020). Such messages contain ideologically biased accusations; the actors are held responsible for the problem and accused of incompetence, malice, or unscrupulousness (Boberg et al., 2020). For example, medical actors were at the center of public debate during the pandemic, speaking out in the news media or advising policymakers. They also often recommended COVID-19 vaccination (Rapisarda et al., 2021). Therefore, antivaccine misinformation can be expected to criticize and blame them. Based on this reasoning, we assume that *partially false information criticizes medical actors more often than completely false information does (H3a).*

Media and political actors are also often attacked and discredited in misinformation, such as by accusing them of deliberately misleading citizens and deceiving them to their benefit (Boberg et al., 2020). Therefore, we postulate that *misinformation on COVID-19 vaccination contains criticism of actors from media and politics* (*H3b*).

Researchers have highlighted that misinformation with broad reach, attracting significant attention from social media users, is particularly concerning because users interact with and propagate it (Marwick and Lewis, 2017; Freelon and Wells, 2020). This type of misinformation transforms its negative consequences from an individual issue to a societal problem. On the one hand, the widespread reach of misinformation can be attributed to its emotionally charged content. Studies have highlighted how misinformation often leverages to capture attention and elicit strong reactions, thus increasing its shareability and impact. On the other hand, producers of misinformation also benefit financially due to the platforms' advertising logic, where sensational and emotionally engaging content often achieves higher viewership (Zollo et al., 2015; Staender et al., 2021). The emotional appeal of misinformation can both be a tool for increased dissemination and a factor in its believability, making it a crucial aspect to study. Therefore, we ask *to what extent partially false and completely false videos with a broad reach (e.g., 20,000 views or more) differ in emotional-appealing and content-related design aspects from videos with a smaller reach (RQ1).* Misinformation is not a one-size-fits-all phenomenon; it employs a variety of strategies to maximize reach and influence. Producers of misinformation may use a neutral tone to gain credibility and a sense of legitimacy, especially in contexts where overt emotionalism might trigger skepticism. Conversely, they may use emotional appeals

to exploit cognitive biases and emotional reactions, ensuring rapid dissemination and engagement. Understanding the nuanced use of these rhetorical strategies is key to developing effective countermeasures against misinformation.

To investigate what misleading content users on YouTube were exposed to during the pandemic and what untruths were spread about the COVID-19 vaccine, we conducted a standardized content analysis of misinforming videos. In the following, we describe our approach in detail.

Methods and data

To test our hypotheses, we investigate which types of misinformation are present on YouTube, which statements such information contains, which speakers are present, and what blame attributions are made. We followed the procedure of Brennen et al. (2020) and created a data corpus with misinformation about COVID-19 vaccination. First, we identified leading actors from Switzerland who published misinformation on YouTube in German or French based on extensive research in the respective online ecosystem. In determining the leading actors among content creators, we employed specific criteria, including the number of subscribers, average views per video, frequency of content related to COVID-19 vaccination, and the level of user engagement (likes, comments, shares) their videos elicited. This approach allowed us to identify those creators who had a significant influence in shaping public discourse around COVID-19 vaccination on YouTube. Second, we used a snowball approach (references in videos or links in the comment sections) to identify accounts with similar content. These accounts also operated from Germany, Austria, or France. We found 200 accounts that published at least one video and examined whether their videos contained misinformation. Based on Humprecht (2019), we categorized misinformation as statements about COVID-19 that could be refuted by information from authorities and organizations (i.e., the Federal Office of Health, WHO) or fact-checkers. We sampled 450 German[2] - and French-language videos with misinformation about the COVID-19 vaccine, which were published between July 2020 and November 2021.

We conducted a quantitative content analysis. The intercoder reliability test of the three trained coders yielded satisfactory results: S-Lotus >0.74 (Fretwurst, 2015)[3] (see the Appendix for the full results). Next, we examined whether the videos' statements about vaccination were entirely fabricated or partially false (mixed correct and false information). For example, statements were coded as partially false if an image sequence was not manipulated but appeared in the wrong context (wrong description, wrong caption, originally from a different time/context) or correct or accurate information was misinterpreted or shared with a false context. To ensure high reliability for the coding of partially and completely false information, one project leader and one student coder coded the videos regarding uncertainty.

To code the main topic of a video, we analyzed its headline and teasers. Then, we relied on the *COVID-19 Vaccine Handbook*'s categorization of misinformation topics (Lewandowsky et al., 2021). We coded the topics of safety, efficacy, side effects, scientific evidence, and the sources or speakers mentioned (e.g., authors/bloggers, scientists, politicians, physicians, and laypersons). To measure elements of misinformation about COVID-19 vaccination, we relied on Kata's (2010) study of antivaccination websites.

To measure conspiracy narratives, we coded whether videos contained elements of conspiracy theories. For example, such videos assert that a group of people is conspiring secretly to deceive society (e.g., politicians or businesspeople are organized in a secret society because they have evil intentions). Examples of such claims include Bill Gates developing the coronavirus to earn money or the Chinese government spreading it to harm the West. Moreover, we coded whether videos claimed that national vaccination campaigns are excessive state control that restricts civil rights; vaccination policy is based on profit (i.e., the government makes money from vaccinations); the dangers of diseases are exaggerated by those in power or the media to scare people (scaremongering; e.g., the coronavirus is not as bad as the media want to make people believe, to spread panic); vaccines contain poisons (e.g., rat poison); COVID-19 vaccines cause diseases (e.g., autism) or severe side effects (e.g., thrombosis, which is more dangerous than the symptoms of COVID-19); or COVID-19 is rare, non-contagious, or relatively harmless (trivialization).

References to science were measured using the following variables: numbers-based evidence (e.g., the relevant argumentation was supported by the mention of numbers) and scientific evidence (e.g., the argumentation was based on scientific evidence, such as references to scientific studies or reviews).

Antielitism was measured by coding criticism of actors from medicine, politics, and the news media. It was coded on blaming individual actors or groups of actors for current problems or accusing them of not responding appropriately (e.g., "The government is curtailing our liberties with the certificate requirement;" "The media is hiding bad side effects of vaccinations").

We categorized each video by genre, including discussions, interviews, animation, satire, educational (featuring an actor or offscreen narrator explaining a subject, similar to a documentary), news reports/broadcasts, commercials, individuals expressing their opinions, demonstrations, and other genres.

Finally, to answer RQ1 about differences between widely and less widely viewed misinformation videos, we measure views, user reactions (i.e., likes, dislikes, and comments), emotional-appealing images, and content-related design elements. Such elements from the video description included links to anti- and provaccine websites, links to videos by the author, advertising for antivaccine media (e.g., books or DVDs), requests for donations, and links to news media websites. Emotional-appealing images included images of victims (e.g., harmed children) or syringes. Based on an empirical assessment of our data, we set the threshold between widely and less widely viewed videos at 20,000 views. Our data shows a significant gap between these groups: Most videos (n = 345) had only a few views (mostly below 100), and a smaller group (n = 105) received 20,000 or significantly more.

2 German-language videos included Swiss-German content.

3 For a similar approach, see Blassnig et al. (2019).

All content-related variables were collected as dummies and recoded into metric variables (ranging from 0 to 1).

Results

Our main interest is to compare different types of misinformation. Research has distinguished between partial and complete false misinformation. The first is of particular concern because users recognize it less easily, so it may have a more significant potential for deception. In addition, platforms and fact-checkers can poorly identify and eliminate such content. As producers of antivaccine misinformation may want to convince many users of their narratives, H1 postulates that YouTube contains more partially than completely false information about the COVID-19 vaccine. To test H1, we analyzed different types of misinformation in the videos. Our analysis shows that completely false information was generally more frequent (61%; $n = 363$) than partial misinformation (39%; $n = 177$), in which true and false information are mixed or interpreted misleadingly. Both completely (42%; $n = 110$) and partially false (36%; $n = 61$) information appeared most often in videos by individuals who expressed their opinions (36%, $n = 61$). Explanatory videos accounted for 19% ($n = 50$) of the completely false and 19% ($n = 32$) of the partially false videos, followed by interviews, which accounted for 10% ($n = 25$) of the completely false and 17% ($n = 30$) of the partially false videos. Based on this finding, we reject H1.

We compared views and user reactions to partially and completely false YouTube videos to understand how users responded to them (see Table 1). The results show that videos containing partially false information received more views ($M_{views} = 94{,}621.82$), likes ($M_{likes} = 4{,}608.40$), dislikes ($M_{dislikes} = 140.48$), and comments ($M_{comments} = 733.62$) compared to completely false information ($M_{views} = 38{,}797.31$; $M_{likes} = 2{,}206.22$; $M_{dislikes} = 65.69$; $M_{comments} = 317.11$).

In the next step, we compared content features of partially vs. completely false information (see Table 2). Based on previous research, we hypothesized that completely false information more often includes conspiracy narratives (*H2a*) and claims about vaccination's side effects and safety (*H2b*). As Table 2 shows, completely false information contained significantly more references to conspiracy narratives ($M = 0.55$), accusations of excessive state control that restricts liberty rights ($M = 0.43$), accusations of profit motives ($M = 0.28$), and accusations of scaremongering ($M = 0.27$) compared to partially false information ($M_{conspiracy} = 0.15$; $M_{control} = 0.33$; $M_{profit} = 0.20$; $M_{scaremongering} = 0.27$), leading us to accept *H2a*.

Similarly, aspects of side effects and safety were present more often in completely than partially false videos. For example, such

TABLE 1 Views and user reactions to partially and completely false YouTube videos.

	Partially false videos		Completely false videos	
	M (SD)	*n*	*M (SD)*	*n*
Views	94,621.82 (280,279.21)	176	38,797.31 (182,668.21)	273
Likes	4,608.40 (9,664.11)	171	2,206.22 (6,969)	264
Dislikes	140.48 (485.17)	171	65.69 (301.36)	264
Comments	732.62 (1,847.49)	161	317.11 (1,176.26)	229

$N = 450$. All values are statistically different based on *t*-tests for independent samples; $p < 0.001$.

TABLE 2 Content features of partially and completely false YouTube videos.

	Partially false videos ($n = 177$)	Completely false videos ($n = 373$)
	M (SD)	*M (SD)*
Conspiracy narratives	0.15 (0.36)	0.55 (0.50)
State control	0.33 (0.47)	0.43 (0.50)
Profit reasons	0.20 (0.40)	0.28 (0.45)
Scaremongering	0.13 (0.34)	0.27 (0.44)
Toxins	0.02 (0.15)	0.22 (0.41)
Disease-causing	0.09 (0.29)	0.24 (0.43)
Severe side effects	0.34 (0.48)	0.43 (0.50)
Trivialization	0.15 (0.36)	0.21 (0.41)
Numbers-based evidence	0.30 (0.46)	0.22 (0.41)
Scientific evidence	0.24 (0.43)	0.17 (0.38)
Scientific dissent	0.23 (0.42)	0.14 (0.35)
Criticism of medical actors	0.13 (0.34)	0.21 (0.41)
Criticism of institutions (e.g., WHO, UN)	0.09 (0.28)	0.17 (0.38)
Criticism of political actors	0.40 (0.49)	0.50 (50)
Criticism of politics	0.35* (0.48)	0.40* (0.49)
Criticism of media actors	0.07 (0.25)	0.17 (0.37)
Criticism of the news media	0.64* (0.48)	0.61* (0.49)

$N = 450$. All values are statistically different based on *t*-tests for independent samples; $p < 0.001$, except for values marked with *.

TABLE 3 User reactions to widely and less widely viewed YouTube videos.

	Videos with <20,000 views ($n = 344$)		Videos with more than 20,000 views ($n = 105$)	
	M (SD)	*n*	*M (SD)*	*n*
Likes	488.03 (1,681.98)	332	11,732.56 (13,421.20)	103
Dislikes	11.64 (364.08)	332	730.03 (32.80)	103
Comments	65.30 (142.58)	302	1,941.47 (2,695.01)	88

$N = 450$. All values are statistically different based on *t*-tests for independent samples; $p < 0.001$.

TABLE 4 Hyperlinking, commercialization, and emotionalization in widely and less widely viewed YouTube videos.

	Videos with <20,000 views ($n = 344$)	Videos with more than 20,000 views ($n = 106$)
	M (SD)	*M (SD)*
Negative links (links to antivaccine websites)	0.09 (0.28)	0.23 (0.42)
Positive links (links to provaccine websites)	0.00* (0.05)	0.00* (0.00)
Links to other videos by the author	0.19 (0.39)	0.40 (0.49)
Links to news media websites	0.35 (0.48)	0.46 (0.50)
Advertisement (e.g., antivaccine books, DVDs for sale)	0.14 (0.35)	0.38 (0.49)
Donation account details	0.24 (0.43)	0.43 (0.50)
Support requests (e.g., to support the website/antivaccine movement)	0.09 (0.29)	0.41 (0.49)
Images of victims (e.g., images of harmed children)	0.04 (0.21)	0.15 (0.36)
Images of syringes (e.g., images of frightening syringes)	0.09 (0.29)	0.22 (0.41)

$N = 450$. All values are statistically different based on *t*-tests for independent samples; $p < 0.001$, except for values marked with *.

videos included claims that vaccines contain toxins ($M_{completely} = 0.22$; $M_{partially} = 0.02$), cause severe diseases ($M_{completely} = 0.24$; $M_{partially} = 0.09$), and have side effects that are more severe than COVID-19 ($M_{completely} = 0.43$; $M_{partially} = 0.34$) and that side effects are trivialized ($M_{completely} = 0.21$; $M_{partially} = 0.15$). Based on these findings, we accept H2b.

Antielitism in the form of criticism of different actor types also appeared more frequently in completely false videos. These videos included criticisms of medical actors (e.g., doctors; $M = 0.21$), supranational institutions (e.g., the WHO or the United Nations; $M = 0.17$), political actors ($M = 0.50$), and media actors (e.g., journalists; $M = 0.17$) more frequently compared to partially false videos ($M_{medical} = 0.13$; $M_{institutions} = 0.09$; $M_{political} = 0.40$; $M_{media} = 0.07$). Criticisms of general elites, such as politics in general or the media, frequently appeared in both types of misinformation but slightly more often in completely false videos. Therefore, we accept *H3a* and *H3b*.

To answer *RQ1*, we compared videos with more and <20,000 views. Our analysis shows that videos with a higher reach differed significantly from other videos: those with more than 20,000 views ($n = 105$) contained 54.3% partially false information ($n = 57$) and 45.7% utterly false information ($n = 48$). The difference was even greater for videos with more than 50,000 views ($n = 75$). These contained 59.2% ($n = 21$) partially false and 40.8% completely false information. Finally, for videos with over 150,000 views ($n = 35$), 60% were partially false ($n = 21$), and 40% were completely false ($n = 14$).

As Table 3 shows, videos with more than 20,000 views received significantly more user reactions in the form of likes, dislikes, and comments than videos viewed less often.

Those videos also stood out regarding elements of hyperlinking, emotionalization, and commercialization (see Table 4): Videos with more than 20,000 views more frequently contained links to antivaccine websites ($M_{completely} = 0.23$; $M_{partially} = 0.09$), other YouTube videos by the author ($M_{completely} = 0.40$; $M_{partially} = 0.19$), and news media websites ($M_{completely} = 0.46$; $M_{partially} = 0.35$). Advertisements for antivaccination content, such as books or DVDs ($M_{completely} = 0.38$; $M_{partially} = 0.14$) and requests for donations ($M_{completely} = 0.43$; $M_{partially} = 0.24$) or support ($M_{completely} = 0.41$; $M_{partially} = 0.09$) were also more frequent. In addition, emotional-appealing visuals of victims ($M_{completely} = 0.15$; $M_{partially} = 0.04$) or syringes ($M_{completely} = 0.22$; $M_{partially} = 0.09$) also appeared more frequently in completely false videos.

In sum, hyperlinking, commercialization, and emotionalization elements were found more frequently in videos with a broader reach (more than 20,000 views).

Discussion

Our research has predominantly identified completely false YouTube videos about COVID-19 vaccination, characterized by conspiracy theories, anti-elitism, and misinformation about vaccine side effects and safety. These videos aim to create doubt and mistrust by suggesting malicious motives behind the vaccine development and accusing news media of complicity.

Partially false information, while less frequent, typically involved misleading interpretations of scientific evidence and debates. These videos garnered more user attention, as indicated by view, likes, dislikes, and comments. This observation aligns with literature suggesting that partially false information can be perceived as more credibly and persuasive (Hameleers et al., 2021), potentially due to its scientific framing and subtler allusions. However, our study does not establish causality but rather describes these observed patterns.

Furthermore, we found that videos with a broad reach (over 20,000 views) distinctly use emotional appeals and content-related strategies to enhance their reach. These high-reach videos received more user reactions and exhibited a higher degree of commercialization, such as donation requests and product advertising. They effectively engage in misdirection by redirecting users to related sites through links and appealing for support, which strengthens the antivaccine network. Moreover, high-reach videos frequently utilized emotionalizing imagery to capture attention and amplify their message. This strategy is particularly evident in partially false videos, which may remain online longer due to their subtle nature (Knuutila et al., 2020). The pervasive use of emotional appeal in the videos demonstrates a deliberate tactic to resonate with and engage viewers deeply, thereby amplifying their reach and impact on public opinion about vaccination.

In sum, our research contributes to the understanding of the nature and dynamics of COVID-19 vaccine misinformation on

YouTube. It underscores the need for vigilant monitoring and proactive strategies by social media platforms and fact-checkers to address both completely and partially false information.

Conclusion

The proliferation of misinformation on platforms like YouTube significantly impedes public health efforts, by undermining disease control and health promotion initiatives (Knuutila et al., 2020). Current research shows that users, especially those skeptical of vaccinations, are less likely to get vaccinated and have less confidence in vaccination after seeing misinformation on YouTube about COVID-19 vaccination (Kessler and Humprecht, 2023). Moreover, misinformed users are more likely to believe that alternative remedies, such as chloroquine, are more effective than vaccination (Bertin et al., 2020). Such a situation could be particularly problematic in countries such as Switzerland, where about a quarter of the population was initially skeptical of COVID-19 vaccination (Gordon et al., 2020). By May 2022, <70% had received at least two doses of vaccine.[4] Vaccine hesitancy can vary from person to person and is influenced by a complex interplay of factors, such as misinformation, lack of trust in authorities and media, personal belief and values, and experiences with vaccination (Wilson and Wiysonge, 2020). However, if certain content is seen frequently, then the likelihood of it being seen as believable increases (Ecker et al., 2017).

We aimed to expand our understanding of different types of misinformation on COVID-19 vaccination on YouTube outside of the well-researched U.S. context. From our analysis of French- and German-language YouTube videos, we discovered a multifaceted landscape of misinformation characterized by varying degrees of factual distortion and a range of actors with differing intentions and strategies. Particularly concerning is our finding that videos containing partially false information had greater reach and engagement, suggesting that subtler forms of misinformation might be more insidious and influential. Moreover, completely false videos were more frequent, but partially false videos had a broader reach and provoked more user reactions. Such misinformation was disseminated by various actors, including individuals, groups, and (alternative) media outlets. The most common claims in the videos were related to vaccine safety and efficacy, with many videos promoting antivaccination sentiment and conspiracy theories. Our analysis also revealed that videos with a higher reach, as indicated by view counts, tended to have more elements of commercialization and emotionalization. This study has several limitations, which need to be considered. First, the content analysis was conducted on a sample of 450 YouTube French- and German-language videos containing misinformation about COVID-19 vaccination, which may only represent some misinformation on or across other social media platforms. Therefore, the findings may not be generalizable to different types of misinformation or misinformation in other languages. Second, the study focuses on YouTube and visual content, which may not capture the full extent of misinformation related to COVID-19 vaccination on other social media platforms or online sources. Third, the analysis was conducted at a specific time and may not capture changes in misinformation patterns or content on YouTube.

Finally, our study enriches the understanding of misinformation on YouTube, especially in the under-researched contexts of Swiss audiences. By highlighting specific patterns of misinformation in these languages, our research underscores the need for targeted strategies to address misinformation in diverse linguistic and cultural settings. While emphasizing the importance of collaborative efforts to combat misinformation, we also recognize the unique contribution of our findings. These insights not only contribute to a more global understanding of misinformation but also underline the importance of localized research in informing effective, culturally sensitive strategies.

In summary, our research calls for an appreciation of diverse linguistic and cultural perspective in the fight against misinformation, advocation for both international cooperation and context-sensitive approaches.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical approval was not required for the study involving human data in accordance with the local legislation and institutional requirements. The social media data was accessed and analyzed in accordance with the platform's terms of use and all relevant institutional/national regulations.

Author contributions

EH and SHK made significant contributions throughout the research process, participated in the design of the study, and were involved in data collection and ensuring the quality and reliability of the gathered information. EH took the lead in conducting the empirical analysis, employing statistical techniques, data interpretation to derive meaningful insights from the collected data, played a central role in the synthesis and organization of the findings, and crafting the initial version of the manuscript. All authors contributed to the article and approved the submitted version.

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4 https://www.covid19.admin.ch/de/vaccination/doses

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Appendix

TABLE A1 Reliability values.

Variable	Lotus coefficient
Video genre	1.00
Negative links (links to antivaccine websites)	0.85
Positive links (links to provaccine websites)	0.96
Links to other videos by the author	0.85
Advertisement	0.96
Donation account details	1.00
Support requests	0.85
Links to news media websites	1.00
Trivialization	0.89
Completely false	0.89
Partially false	0.89
Numbers-based evidence	0.81
Scientific evidence	0.93
Images of victims	0.85
Images of syringes	1.00
Toxins	1.00
Disease-causing	1.00
Severe side effects	0.96
State control	0.78
Profit reasons	0.81
Scaremongering	0.96
Criticism of medical actors	0.78
Criticism of politics	0.74
Criticism of political actors	1.00
Criticism of institutions	0.89
Criticism of the news media	0.85
Criticism of media actors	0.75
Average	0.89

$n = 27$.

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Factors influencing user's health information discernment abilities in online health communities: based on SEM and fsQCA

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Introduction: Online health communities have become the main source for people to obtain health information. However, the existence of poor-quality health information, misinformation, and rumors in online health communities increases the challenges in governing information quality. It not only affects users' health decisions but also undermines social stability. It is of great significance to explore the factors that affect users' ability to discern information in online health communities.

Methods: This study integrated the Stimulus-Organism-Response Theory, Information Ecology Theory and the Mindsponge Theory to constructed a model of factors influencing users' health information discernment abilities in online health communities. A questionnaire was designed based on the variables in the model, and data was collected. Utilizing Structural Equation Modeling (SEM) in conjunction with fuzzy-set Qualitative Comparative Analysis (fsQCA), the study analyzed the complex causal relationships among stimulus factors, user perception, and the health information discernment abilities.

Results: The results revealed that the dimensions of information, information environment, information technology, and information people all positively influenced health information discernment abilities. Four distinct configurations were identified as triggers for users' health information discernment abilities. The core conditions included information source, informational support, technological security, technological facilitation, and perceived risk. It was also observed that information quality and emotional support can act as substitutes for one another, as can informational support and emotional support.

Discussion: This study provides a new perspective to study the influencing factors of health information discernment abilities of online health community users. It can provide experiences and references for online health community information services, information resource construction and the development of users' health information discernment abilities.

KEYWORDS

online health communities, health information discernment abilities, information ecology theory, perceived value, fsQCA

1 Introduction

With the rapid advancement of artificial intelligence and Internet technology, various online health services have emerged one after another, offering opportunities to transform the traditional healthcare industry (1–3). The public's health awareness and health literacy are also constantly improving, leading to an increasing demand for health information (4, 5). Online Health Communities (OHCs) serve as open online interactive platforms where users, including the general public, patients and their families, caregivers, and medical professionals, can engage in discussions about health and medical issues, seek expert consultations, share treatment experiences, and seek social support (6, 7). OHCs play a crucial role in disseminating health information, assisting users in making health Decisions, and preventing the occurrence of diseases. As a new model of "Internet + medical health," OHCs have rapidly emerged and developed (8). Additionally, OHCs can help reallocate idle medical resources, promote more efficient use of medical resources, solve the problem of mismatch between supply and demand of health services, and thereby improve the doctor-patient relationship (9–11). According to the 53nd Statistical Report on China's Internet Development released by the China Internet Network Information Center (CNNIC), as of December 2023, the number of Chinese Internet users has reached 1.092 billion, with an internet penetration rate of 77.5%. The number of Chinese Internet healthcare users has reached 414 million, accounting for 37.9% of the overall Internet user base (12). Internationally renowned Internet healthcare platforms such as Haodaifu, Doctor on Demand, and Patients Like Me have risen rapidly around the world (13, 14). Online health communities have become a vital source for people to obtain health information and occupy an important position in the modern healthcare industry.

Due to the openness, commerciality, and profit-seeking nature of online platforms, information quality problems emerge one after another in OHCs, such as the spread of false and difficult-to-distinguish health information to gain users attention and information epidemics, which have increased the difficulties of information quality governance in these communities (15, 16). Exposure to distorted information inevitably affects the future acceptance of accurate health knowledge. If they make judgments based on this invalid, incomplete, or even wrong information, it will not only affect people's health Decisions, but also cause damage to social stability. For example, during the COVID-19 epidemic, the Iranian people blindly believed in unproven treatment methods. To prevent COVID-19, they consumed high-concentration alcohol, causing more than 600 deaths and more than 3,000 people being poisoned (17, 18). This posed a serious threat to public health, with harmful consequences for global health and wellbeing (19).

In recent years, countries around the world have taken various measures to improve the quality of information on online health platforms. For instance, the European Union has issued the Strengthened Code of Practice on Disinformation (20). China has released the Guidelines on the Establishment of a Sound Mechanism for the Publication and Dissemination of Health Science Knowledge Across the Media and established the China Internet Joint Rumor Refutation Platform (21). In addition, the Swiss Health On the Net Foundation has formulated the HONcode guidelines. From the perspective of information technology, scholars have explored false information filtering technology and health information monitoring technology. Guo and Wei (22) used block matching and fuzzy neural networks to effectively improve the classification and identification efficiency of false information on Weibo, specifically about China's context. Wan et al. (23) established a database of false drug advertisements and real drug advertisements on Sina Weibo, and confirmed that the use of a support vector machine classifier to classify false drug advertisements has the best effect, providing an effective method for the government to identify and combat false advertisements.

Scholars have conducted relevant studies on health information discernment from multiple perspectives. Wang and Zhou (24) explored the current status of the health information discernment abilities of the older adult in the social media environment, and evaluated the impact of learning a pseudo-health information feature list on improving their discernment abilities. Zhang (25) explored the status of college students' health information discernment abilities in a complex online environment and proposed specific strategies to enhance their health information discernment abilities. According to Li and Zhang (26), college students' health information discernment abilities were mainly affected by their location of birth, family income, and attention to health information. Hou and Yang (27) used semi-structured interviews to collect data on the health information discernment ability of urban residents in China, and constructed a model of factors influencing health information discernment ability. These factors mainly include personal characteristic factors, information factors, institutional factors, and social class factors. Qiu et al. (28) identified that the health information discernment abilities of WeChat users were most significantly influenced by content updates, information readability, and government propaganda.

In terms of research perspectives, most studies focus on various demographic groups of internet users and social media users. Eysenbach et al. (29) found that factors such as the authority of information sources, website layout and appearance, readability of information, and authoritative certifications significantly impact the health information discernment ability, through interviews with internet users. Zhang and Li (30) conducted a survey among internet users of different age groups and discovered that age, gender, place of residence, and the level of interest in health information significantly influence the health information discernment abilities. However, most studies predominantly take "internet users" and "social media users" as a whole research subject, neglecting to specifically focus on users of online health communities (OHCs), who typically have a stronger need for health information. OHCs users are generally more actively engaged with health information compared to regular internet users. Unlike other social media platforms, OHCs are specialized in providing online health services, making them more vertical and targeted. Users participate in these communities to improve their health status, sharing common health goals. They actively discuss health issues, share experiences, and seek social support or informational support related to their specific health concerns. This interaction among users fosters a sense of resonance and cohesion. Health information disseminated among users through homogeneous communication significantly increases its credibility and propagation power. However, the large amount of indistinguishable true and false health information in OHCs poses significant risks. If false or incorrect information is trusted and widely spread, it can adversely affect users' health Decisions, making it critical to enhance the ability of OHC users to discern health information.

In terms of research methods, some studies utilized computer technology to explore health information detection (31, 32). While more studies relied on qualitative interviews and grounded theory to examine factors influencing individual discernment abilities (27, 33, 34). These methods possess a degree of subjectivity and May overlook the interrelationships among influencing factors (28). More objective methods are required to evaluate the importance of the influencing factors. Most of the studies focused on the net effect of a single influencing factor on the user's health information discernment abilities, ignoring the synergistic effect of the configuration of multiple factors on the results. Nevertheless, users' health information discernment activity is a complex Decision-making process. The process is often not the result of a single factor, and the intricate interrelationships among these factors remain to be explored.

To address this research gap, this study took OHCs users in China as the research object, utilizing Stimulus-Organism-Response Theory, Information Ecology Theory and the Mindsponge Theory as theoretical guidance. It comprehensively considered four factors: information, information environment, information technology, and information people. It makes up for the shortcomings of the study of a single factor, and aims to establish a comprehensive model of factors influencing users' health information discernment abilities. In addition, this study combined Structural Equation Modeling (SEM) with fuzzy-set Qualitative Comparative Analysis (fsQCA), which avoids the limitation that SEM can only examine the net effect of a single variable that affects users' health information discernment abilities. This combination allows for a more detailed and in-depth analysis and understanding of the combined influence of multiple factors. The configuration results provide suggestions for improving users' health information discernment abilities and improving OHCs functions.

2 Research hypothesis and model construction

2.1 Theoretical background

2.1.1 Information ecology theory

The concept of information ecology was first proposed by Horton (35). Information ecology theory views information, information people, information technology, and the information environment as a whole. It emphasizes the balance and development of humans, environment, and technology in the information ecosystem, so as to realize the production, dissemination, and utilization of information (36). Within this theoretical framework, the information people is the subject, controlling the information activities within the system. The information itself is the object, existing independently of human will. Information technology serves as the medium for information transmission. The information environment is the field where the interaction between the subject and object occurs. The core issue of this theory is the information behavior generated by the information people and the interactions between the information people and other elements (37).

As a classic theory in the field of explaining user information behavior, information ecology theory has been widely applied in studies on influencing factors of OHCs users' information seeking behavior (38), information adoption behavior (39), information interaction behavior (40), and information sharing behavior (41). Ji and Li (40) explored the willingness for emotional interaction among OHCs users from an information ecology perspective, in which the information dimension includes topic relevance and topic value, the information environment dimension includes group connection and group identity, the information technology dimension includes perceived platform usefulness and perceived function ease of use, and the information people dimension includes health status and health experience. Gao et al. (42) applied the information ecology theory to study the information processing of online health community users, in which the information dimension includes information quality, the information environment dimension includes emotional support and privacy issues, the information technology dimension includes system quality, and the information people dimension includes self-efficacy. Zhang et al. (36) explored the behavior of seeking medical information assistance from an information ecology perspective among OHCs users, where the information dimension includes information accuracy, information relevance, and information timeliness; the information environment dimension includes social acceptability and platform trust; the information technology dimension includes perceived ease of use and perceived usefulness; and the information people dimension includes self-efficacy, health information literacy, and assistance-seeking experience.

Users' discernment of health information is an important part of online health community activities, affecting users' health Decisions and usage experience. The complex influencing factors in health information discernment can also be explained systematically and holistically from the perspective of information ecology theory (43). In this study, from the viewpoint of information factors, users not only need to examine the quality of health information, but also consider whether the source of health information is credible and authoritative, which provides good information resources for their own health Decisions. From the viewpoint of information environment, rich information support and emotional support realms help to create an efficient, orderly, and sustainable user interaction environment, thus improving the efficiency of obtaining correct health information and promoting the quality of community information services. From the viewpoint of information technology, information technology connects users with the community environment. The safe, intelligent, and convenient technology can expedite the realization of platform functions and provide a basic guarantee for the good experience of users. From the viewpoint of information people, users are the most active elements in the process of information active. The driving force and the confidence in the discerning task are related to the flow of health information in the community. Therefore, this study explores the factors influencing the health information discernment abilities of online health community users from four aspects: information (information quality, information source), information environment (informational support, emotional support), information technology (technological security, technological facilitation), and information people (self-efficacy).

2.1.2 Stimulus-organism-response theory

Mehrablan and Russell (44) proposed that the general human behavior model is the "stimulus-organism-response" model, which is used to explain and predict the impact of stimuli from different environments on individual cognition, individual behavior, and personal emotions. The model consists of three parts: stimulus,

organism, and response. Stimulus is defined as some kind of object, event, or characteristic, which can be divided into external stimulus and internal stimulus. Organism, as an intermediary variable, is an individual's psychological transformation mechanism, such as emotional or cognitive changes, which indicates that the behavior of the organism will be affected by the influence of internal factors. Response represents the individual outcome variable, which generally manifests as an approach or avoidance of things (45).

This model has been widely used in studies on individual offline and online behaviors, such as information participation behavior (46). Recently, it has been used to study the online behaviors of individuals in the face of online disinformation and rumors (47). Based on Stimulus-Organism-Response theory, Liu et al. (48) took rumor type and rumor ambiguity as stimulus and perceived authenticity, perceived importance and perceived trust as the organism's perceptual states, and verified the influence mechanism of individual's intention to verify rumor. Wu (49) considered informational dependency and social dependency as stimulus, and investigated how such stimulus led to positive and negative effects within organisms, which in turn affects the individual's perception of misinformation sharing. Xie and Hu (50) regarded perceived credibility as an external stimulus, subjective norms, individual norms, and attitudes as organic states, and the rumor deletion intention and the rumor disproving sharing intention as a response, verifying the rumor correction behavior of social media users and its influence paths.

Additionally, users' perception of health information services in OHCs is closely related to their ability to discern health information. Perceived value is the overall utility assessment of health information attributes by users (51). From the perspective of perceived value, when users perceive that the health information they obtain can bring value to themselves, they generate positive emotions, adopt the information, and further enhance their ability to discern information. Perceived risk is the subjective judgment by users of potential negative outcomes perceived in online health information services (52). Perceived risks include false health information, privacy concerns, privacy breaches, and financial security, among others, which are crucial factors influencing users' use of online health information services (53). Based on the S-O-R theory, Cui (54) found that users' perceived risks have a negative impact on the dissemination of false information on the internet. For health information with higher perceived risks, users need to invest more effort in systematic and rational thinking. In this study, perceived value and perceived risk represent the users' organism perception states, which affect their health information discernment abilities.

It can be seen that the S-O-R theory is very suitable for research on health information in online health communities. Based on the S-O-R theory theoretical framework, this study examined the health information discernment abilities of OHCs users. In this study, when users exchange information in an online health community, they are not only stimulated by external factors, including the information itself, the environment of the community, and information technology; they are also stimulated by their own factors, such as self-efficacy. Therefore, the "stimulus" refers to the information factor (information quality, information source), information environment (informational support, emotional support), information technology (technological security, technological facilitation), and information people (self-efficacy). Under the double stimulation of internal and external factors, the psychological perception of the user will change. This "organism" perceptual state changes, mainly expressed in the size of the perceived risk and perceived value judgment. Finally, the user's "reaction," that is, health information screening ability.

2.1.3 Mindsponge theory

Vuong and Napier (55) proposed a new information processing mechanism: Mindsponge Theory. It describes the psychological mechanism of which a person accepts or rejects new external information (56). First, an individual receives external information through books, media, the Internet, etc. Then, the individual will sift and filter the information according to established values, beliefs, and cognitive frameworks, and categorize the information into useful and useless, credible and non-credible categories. Later, the information that is considered useful and credible will be absorbed and integrated into the individual's cognitive structure, which is similar to the process of a sponge sucking up water, and rejecting incompatible information. The individual May adapt and reconfigure the existing cognitive structure to fit the new information and environment. Ultimately, the reconfigured cognitive structure influences the individual's feedback to the outside world.

This theory has been used to study vaccine production (57), suicidal behavior (58), and health information processing (57, 59). For example, Tanemura et al. (60) explored the differences in individuals' trust levels of risk-only negative health information and benefit–risk negative health information based on the Mindsponge Theory. They found that individuals' trust levels of risk-only negative health information were higher than those of benefit–risk negative health information. Mindsponge theory was also applicable in explaining that learning interventions for individuals that improve individuals' ability in recognizing unreliable COVID-19 information (61).

In this study, when a user receives new health information from an online health community, the user goes through the brain's filtering system to weigh its perceived value and perceived risk. When an individual's perceived value of health information is greater than the risk, then the resulting high level of trust promotes health information uptake. Conversely, when risk outweighs value, i.e., when the perceived adverse consequences of new health information for an individual's health Decisions outweigh its convenience, and health information is perceived to be unreliable, then health information is rejected. In conclusion, users' health information screening activity is an uninterrupted and continuous process of selective information absorption and exclusion in order to maintain psychological and cognitive balance in order to adapt to the complex online health community information environment, thus realizing the improvement of health information discernment abilities.

2.2 Model construction

Based on the information ecology theory, the stimulus-organism-response theory and the Mindsponge theory, this study developed a research model with four dimensions influencing factors: information (information quality, information source), information environment (informational support, emotional support), information technology (technological security, technological facilitation) and information people (self-efficacy). These dimensions serve as the stimulus factors in the research model. Perceived value and perceived risk, two factors that can reflect the user's psychological perception, are used as the

perceptual state in the organism. The user's health information discernment abilities are regarded as the individual's response, which mainly composed of credibility discrimination ability, accuracy discrimination ability, reasonableness discrimination ability and support discrimination ability. Therefore, the research model constructed in this study is shown in Figure 1.

2.3 Research hypothesis

2.3.1 Information, user perception, and health information discernment abilities

In this study, information elements mainly included information quality and information sources. Information quality is a measure of the accuracy, truthfulness, and completeness of health information (62). The health information searched in OHCs includes advice and information on physical conditions, symptoms, and treatment options, which mainly guides users' health Decisions. Obviously, the accuracy and authenticity of information are crucial. When persuasive and high-quality health information is searched for, it can enhance users' perceived benefits from the information, thereby promoting perceived value and better satisfying their own information needs (63). On the contrary, the reliability of information is considered to reduce an individual's perception of risk. Shah and Wei (64) conducted a survey on 630 users during the COVID-19 pandemic and found that source credibility and information quality are significantly positively correlated with perceived value and significantly negatively correlated with perceived risk. Sun and Wu (65) showed that the comprehensiveness and accuracy of COVID-19 information content can affect the public's perceived risk. When health information is incomplete or lacks logical consistency, it can mislead users, increase their concerns, and elevate their psychological risk levels. Therefore, individuals with high perceived risk require more convincing arguments, such as higher quality health information, to reduce their risk perception. Liang et al. (66) drawing on rational choice theory, studied the online health information use of physically disabled individuals and found that information quality and system quality can increase perceived benefits and reduce perceived risks. Therefore, three hypotheses are proposed as follows:

> H1a: Information quality positively influences perceived value.
>
> H1b: Information quality negatively influences perceived risk.
>
> H1c: Information quality positively influences health information discernment abilities.

The information source considers the credibility of the information source, independent of the information's content. In OHCs, users can act as both creators and disseminators of health information, and their knowledge and experience vary. Hence, the source of information is an important factor in information behavior research (67). Shareef et al. (68) pointed out that when the source credibility is low, the recipients discount the value of the information content they receive.

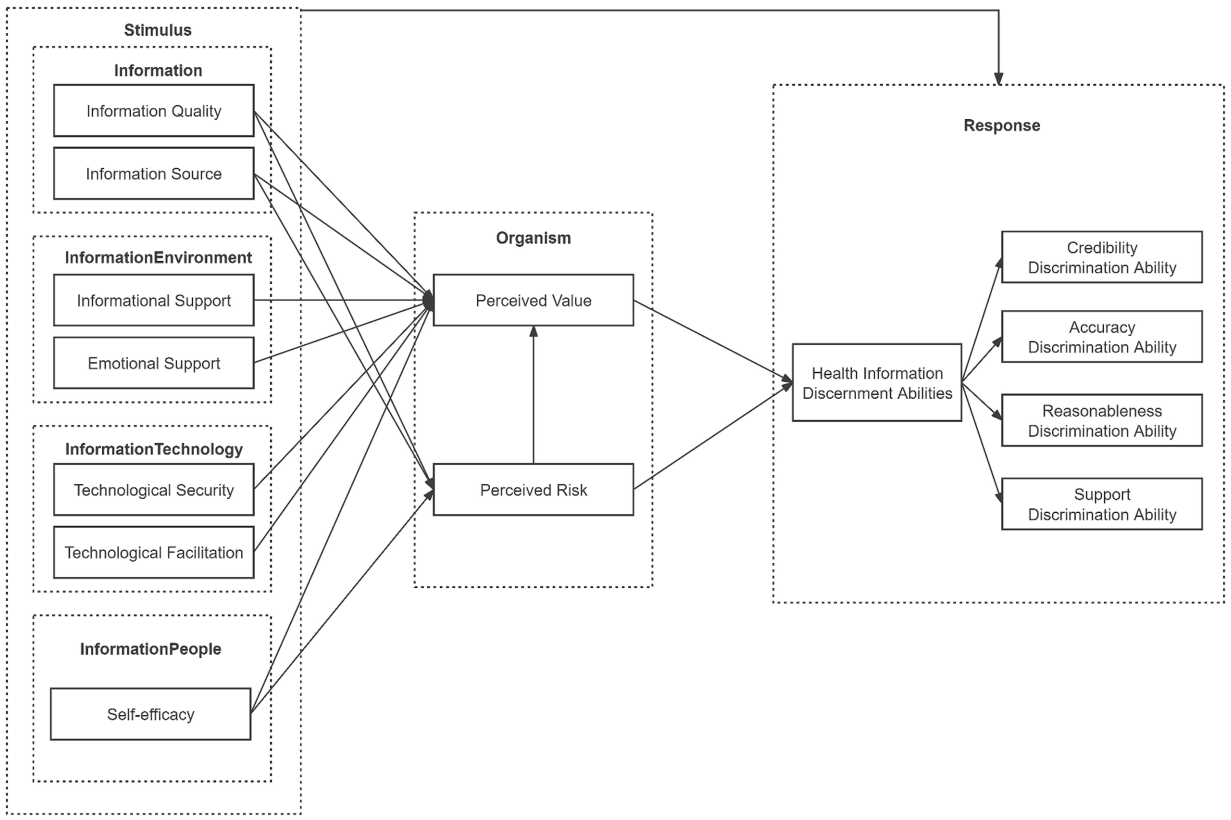

FIGURE 1
Structural research model.

Information from authoritative and professional sources generally has a low perceived risk to users, while information from user-generated content and commercial sources May increase the perceived risk to users. Cha et al. (69) showed that users are more likely to have positive cognitive and affective responses to information obtained from Weibo that have a high level of credibility in its sources. Thompson (70) points out that perceived risk is negatively correlated with the trust of the Internet as an information source. This means that as people's trust in these sources of information Decreases, their perception of risk to health information increases. At the same time, clear information sources are more conducive for users to judge the authenticity of health information. Therefore, three hypotheses are proposed as follows:

> H2a: Information source positively influences perceived value.
>
> H2b: Information source negatively influences perceived risk.
>
> H2c: Information source positively influences health information discernment abilities.

2.3.2 Information environment, user perception, and health information discernment abilities

In this study, the elements of the information environment mainly included informational support and emotional support. Users engage in online discussions and interactions on the internet to obtain specific social support, including emotional, informational, companionship, and technical support (71). Informational support means that users obtain health and medical-related information through searching, consulting, answering, and discussing, including information on medications, healthcare measures, and treatment suggestions (72). Thus, OHCs facilitate the acquisition and sharing of health information and knowledge. According to the Mindsponge theory, when members of OHCs provide valuable advice or timely help to each other, users identify with these new values and assimilate and transform the health information into health knowledge, which is conducive to users' reduction of informational uncertainty and making the right health Decisions, and facilitates their future self-health management. Hu et al. (73) used a case analysis method to conduct an in-depth analysis of the formation mechanism of patients' perceived value, and found that sharing information among members is the key to improving patients' perceived value. Therefore, the following hypotheses are made:

> H3a: Informational support positively influences perceived value.
>
> H3b: Informational support positively influences health information discernment abilities.

Emotional support is expressed as the respect, acceptance, or emotional comfort and encouragement received when an individual is in pain (74). Adequate emotional support is a key factor in creating a favorable atmosphere of interaction that promotes the sustainability of an online health community. Park et al. (75) stated that empathy and encouraging messages in OHCs can provide both emotional support and informational support to members. Emotional support can provide positive energy to other members, making community members feel more confident, in control, and empowered in order to address similar health issues. Receiving emotional support is also an important source of perceived value for users. Kanthawala and Peng (76) found a positive correlation between perceived emotional support and perceived message credibility. In addition, Sun (77) believes that emotional support, as a social resource, is a significant factor affecting the older adult's health information discernment abilities. Therefore, the following hypotheses are made;

> H4a: Emotional support positively influences perceived value.
>
> H4b: Emotional support positively influences health information discernment abilities.

2.3.3 Information technology, user perception, and health information discernment abilities

In this study, information technology elements mainly included technological security and technological facilitation. Technological security in OHCs refers to the security of hardware, software, and related data in online health communities. In the era of big data, the value of information and data is increasing day by day. The subsequent leakage of user privacy information or data loss has become more and more serious. Users have increased concerns about the security of information technology. Studies have shown that in OHCs, the higher the technological security, the more willing users are to share information (52). Internet users can help form a sense of belonging to websites with higher security, thereby further increasing perceived value (78). To enhance security levels from a technological standpoint, it is important to implement advanced data encryption measures, while deploying multi-layered access control mechanisms to ensure that only authorized users can access sensitive information, thereby reducing the risk of information misuse or unauthorized access (79). Additionally, establishing a scientifically efficient information review mechanism is essential to ensure the reliability of information sources, reducing the spread of false and misleading content, and thereby improving the overall quality of information. In such an environment, users can more quickly identify and filter out reliable health information, continuously learn, absorb, and increase their knowledge; ultimately enhancing their discernment capabilities. Some scholars believed that relevant departments must strengthen supervision of the quality of online health information to ensure the security of platform information, thus strengthening the ability of users to resist the interference of misinformation (80). Therefore, the following hypotheses are proposed:

> H5a: Technological security positively influences perceived value.
>
> H5b: Technological security positively influences health information discernment abilities.

The page layout, response speed, functional diversity, and convenience of OHCs all affect users' usability experience and the ease of distinguishing health information. Technological facilitation emphasizes the promotion and support of information technology on people's information behavior. For example, when an OHC has a user-friendly page layout and provides a clear and concise operation guide, it saves users' learning cost and reduces difficulty in using it. Ease of use has a positive impact on users' willingness to use a platform (81). Scholars have found that the difficult interoperability of the platform is one of the barriers to the public's use of online platforms to obtain useful information (82). When constructing online health community information services, leveraging big data technology to deeply analyze

users' website browsing records, search habits, clicking patterns, and browsing durations can accurately capture users' interests and health needs (83).This allows for intelligent and personalized health information recommendations, sparing users the trouble of sifting through vast amounts of information to find what they need. Additionally, providing users with other health information verification tools, such as recommending authoritative health information websites or fake health information features lists, to help users acquire, screen and validate health information more efficiently. Tang et al. (84) found that during the COVID-19 pandemic, the subjective and objective technical support conditions positively influenced the adoption behavior of government short videos. Improving OHCs functions and enriching user experience through technological means improves users' understanding and judgment of health information in several ways. This enables users to more accurately discern valuable health information. Therefore, the following hypotheses are proposed:

> H6a: Technological facilitation positively influences perceived value.
>
> H6b: Technological facilitation positively influences health information discernment abilities.

2.3.4 Information people, user perception, and health information discernment abilities

The information people element in this study mainly consisted of self-efficacy. Warner and Schwarzer (85) argued that general self-efficacy is an overarching self-efficacy of users when facing various challenges or confronting new things. This self-efficacy competence will largely influence people's presumptions about the ability to implement or organize activities. Stronger self-efficacy can better withstand the negative impact of uncertainty factors in the network environment, the easier it is to form a better quality perception and value recognition of the results, resulting in lower perceived risk (86). Wang et al. (87) suggested that the self-efficacy of older adult users who have been in different contexts of family, community, and education for a long time affects their health information needs. Older adult users with high self-efficacy were more adept at expressing differences in the efficacy of health information products, and had a certain degree of ability to discriminate health information products. Therefore, the following hypotheses are made:

> H7a: Self-efficacy positively influences perceived value.
>
> H7b: Self-efficacy negatively influences perceived risk.
>
> H7c: Self-efficacy positively influences health information discernment abilities.

2.3.5 User perception and health information discernment abilities

User perception elements mainly included perceived risk and perceived value. Users assess the utility of health information when using OHCs, retaining information that is valuable for their health needs and refusing to access information that does not deal with their health risks (88). In this study, the perceived usefulness of health information, the emotional pleasure, and the establishment of good interpersonal relationships, as perceived by users, are all manifestations of perceived value. The perceived risk of online health information refers to the user's perception and assessment of the risk level conveyed by the health information, and the subjective judgment and perception of the degree of threat to personal privacy information, physical health, or personal property. According to the Mindsponge theory point of view, the user's processing of health information can be understood as a comparison of the perceived value and perceived risk of new information based on their own existing health knowledge and health experience. The higher the perceived value and the lower the perceived risk of health information, the more likely it is for the user to acquire and utilize. Liu et al. (89) used the S-O-R theory as a theoretical framework and constructed a model of the impact of mobile Medical App content presentation on user adoption willingness influence model. The results show that perceived value plays a mediating role, and the user's perceived value of mobile medical APP content positively influences user adoption behavior. This indicates that health information with a higher value is more likely to capture users' attention, stimulate their interest in in-depth exploration and learning, and motivate them to analyze and validate the information more carefully to enhance their trust in it. This process enhances users' overall health literacy, thereby improving their ability to discern health information.

In contrast, when the information uncertainty is higher or the consequences are more unpredictable, users perceive a higher risk and become more vigilant. They scrutinize the source and content of health information more thoroughly. Zhang et al. (90) found that there was a significant positive correlation between the perceived riskiness of health information and the information avoidance behaviors during the COVID-19 pandemic. This indicates that users become more alert and cautious in the face of riskier information. At the same time, this motivates users to look for more evidence and support to distinguish the difference between misinformation, disinformation, rumors, and correct information. It helps avoid being misled by false or unreliable information. This vigilance helps users develop their discernment skills (91). Perceived value and perceived risk are relative concepts. Research showed that perceived costs and security risks have a great impact on customers' perceived value (92). Therefore, the following assumptions are made:

> H8: Perceived risk negatively influences perceived value.
>
> H9: Perceived value positively influences health information discernment abilities.
>
> H10: Perceived risk positively influences health information discernment abilities.

3 Materials and methods

3.1 Questionnaire design

This study designed a comprehensive questionnaire to investigate the factors influencing health information discernment abilities among users of online health communities. The questionnaire mainly consists of two parts: the basic demographic information of the respondent and the measurement scale. The demographic information part mainly involves gender, age, education level, living area, occupation, monthly income, health condition, attention to health

information, and usage of OHCs. This study set up object screening items: excluding respondents who had never pay attention to health information. The measurement scale encompasses 13 variables: information quality, information sources, informational support, emotional support, technological security, technological facilitation, self-efficacy, perceived value, perceived risk, credibility discrimination ability, accuracy discrimination ability, reasonableness discrimination ability and support discrimination ability.

To ensure the reliability and validity of the questionnaire, the measures of the constructs were mainly adapted from well-established scales used in previous research. In addition, taking into consideration the characteristics of online health communities, the scenarios of questions were revised. The variables were measured using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). Respondents are expected to provide answers based on their actual experiences and usage of online health communities. After completing the questionnaire preparation, four experts in the field were consulted and asked to review the narratives of the measurement items one by one and make corrections to any inappropriate statements, enhancing the scientific validity and rigor of the survey material. The final scale settings are shown in Table 1.

3.2 Data collection

Before conducting the data survey, this study was approved by the Ethics Review Committee of the College of Life Sciences, Central South University (Reference no. 2023-1-34). This study mainly utilized the questionnaire website[1] to conduct the survey. This study primarily conducted an online survey within China. According to the number of downloads of the applications in the App Store, we selected several representative and highly popular applications for distributing the questionnaire. For example, in China, WeChat had been downloaded 9.2 billion times; Sina Weibo had been downloaded 7.2 billion times, and QQ had been downloaded 6.1 billion times. These applications are all in Chinese language. They are not only served as social media platforms, but also a form of OHCs, facilitating quicker access to our target survey participants as many as possible. We employed a snowball sampling method to distribute the questionnaires by participating in topic discussions within WeChat/QQ health communication groups and subsequently inviting friends to share the questionnaires. Additionally, we initiated topic posts in Baidu Tieba forums such as Haodf Online Tieba and DXY Tieba, distributed the questionnaire through Sina Weibo by writing blog posts and commenting on others' blogs, and utilized the comment functions on platforms like the WeDoctor WeChat official account and Meet You app to further disseminate the questionnaire.

Initially, a pre-survey was conducted with 113 users of online health communities to confirm the reliability and validity of the scale, which yielded favorable results and allowed for the formal survey to commence. The formal survey was conducted from September 7, 2023, to October 26, 2023. Finally, 772 questionnaires were received.74 respondents who had never paid attention to health information were excluded from the screening items. Furthermore, 43 questionnaires were removed due to the presence of abnormal data such as (1) choosing the same answer for all questions, (2) logical inconsistencies, (3) completing time <2 min, and (4) identical IP addresses for multiple respondents. This resulted in a final data set of 655 valid responses. According to the sample size requirements of the questionnaire survey, the sample size should be 5–10 times the number of scale question items (93), so the effective sample size of this study meets the requirements.

3.3 Analytical methods

This study primarily adopted the method of SEM for model validation. It is mainly used in social sciences, behavioral sciences, biostatistics, and other fields, aiding researchers deeply explore and understand potential causal relationships in complex data (94). Thus, SEM was used in this study to test hypotheses and analyze the research model. The data analysis involved two main steps. Firstly, the reliability and validity tests of the scale were conducted in this study. Reliability was evaluated using Cronbach's alpha, calculated through SPSS, while convergent and discriminant validity were tested using Confirmatory Factor Analysis (CFA) via Amos 23.0. Secondly, the goodness of fit was calculated to analyze the effect size of the research model and the fit between the research model and the observed data. The magnitude and significance of the path coefficients were calculated to test the hypotheses of the theoretical model and to test the relationship among the latent variables (95).

SEM can identify and explore paths of influence between latent variables, examining both direct and indirect effects. It can better analyze the net effect of antecedent variables on the outcome variables. Inversely, it cannot analyze the complex causal relationships formed by the interdependence of multiple antecedent variables. In contrast, fsQCA assumes an asymmetric relationship between independent and dependent variables, acknowledging that multiple paths and solutions can lead to the same outcome. Based on SEM analysis, fsQCA supplements the exploration of how various influencing factors interact in a multiply and concurrently manner with the outcome variable (96). Studies have shown that the combination of SEM and fsQCA can provide a more comprehensive and in-depth analysis, enhancing the explanatory and predictive power of scientific theories (97). fsQCA is an analytical technique that combines fuzzy set theory with Boolean logic, which requires the data to be calibrated, and to be classified and degrees simultaneously through set affiliation. Then, the necessity and sufficiency analysis of the sample data is performed, from which finally the multifactorial combinations of the outcome variables are generalized to provide different theoretical paths for a given outcome (98).

4 Results

4.1 Sample characteristics

SPSS 25.0 was used to process the survey results. The demographic information of the survey respondents is shown in Table 2. The number of males is slightly higher than the number of females. 35.42% of the participants were aged between 18 and 40 years old. A total 65.50% of the participants had a bachelor's degree or above. 74.40%

1 https://www.wenjuan.com/s/IzaM3e4

TABLE 1 Measurement items for the survey questionnaire.

Construct	Item labels	Items content	Source
Information quality	IQ1	The health information provided by OHCs is authentic and reliable.	Wang and Strong (116), Wixom and Todd (117)
	IQ2	The health information provided by OHCs is highly useful.	
	IQ3	The health information provided by OHCs is comprehensive.	
	IQ4	The health information provided by OHCs is easily comprehensible.	
Information source	ISE1	The health information provided by OHCs comes from credible sources.	Zhao and Du (118)
	ISE2	The health information provided by OHCs is based on scientific evidence.	
	ISE3	The health information provided by OHCs comes from knowledgeable sources.	
	ISE4	The health information provided by OHCs comes from reputable experts or authoritative institutions.	
Informational support	IST1	When I need to discern health information, the members of OHCs can provide me with advice.	Liang et al. (74)
	IST2	When I need to discern health information, members of OHCs can provide me with relevant evidence or clues.	
	IST3	When I need to discern health information, members in OHCs inform me about the causes.	
	IST4	When I need to discern health information, members of OHCs offer me correct information.	
Emotional support	ES1	When I need to discern health information, members of OHCs can provide me with encouragement and comfort.	Johnson and Lowe. (119)
	ES2	When I need to discern health information, members of OHCs will listen to my emotions.	
	ES3	When I need to discern health information, members of OHCs assist me, making me feel warm.	
	ES4	When I need to discern health information, members of OHCs help me alleviate my anxiety.	
Technological security	TS1	Using OHCs for health information discernment does not result in the exposure of user data.	Zhang et al. (120), Zhou (15)
	TS2	OHCs prioritize the utmost protection of user privacy for everyone.	
	TS3	Using OHCs for health information discernment brings me a great sense of reassurance.	
	TS4	OHCs possess the technical capabilities to ensure the security of information during the process of discernment.	
Technological facilitation	TF1	OHCs offer a wealth of functionalities and user-friendly interfaces that meet my needs for health information discernment.	Zlatolas et al. (121)
	TF2	OHCs offer multiple ways for discerning health information.	
	TF3	I prefer using feature-rich OHCs for health information discernment.	
	TF4	Specific modules in OHCs motivate me to actively discern health information.	
Self-efficacy	SE1	I am confident in addressing doubts about the accuracy of health information in OHCs.	Chen and Hung (122)
	SE2	I am confident in my ability to find reliable and trustworthy health information in OHCs.	
	SE3	I am confident to use correct health information from OHCs to make appropriate decisions regarding my health.	
	SE4	My knowledge and experiences are helpful in discerning health information in OHCs.	
Perceived value	PV1	Using OHCs for discerning health information has saved me time, energy, and money.	Yang et al. (123)
	PV2	Using OHCs for discerning health information brings me happiness.	
	PV3	Using OHCs for discerning health information has enhanced my knowledge of health and information.	
	PV4	Using OHCs for discerning health information has elevated my health literacy and information literacy.	
	PV5	Using OHCs for discerning health information has enhanced my ability to discern health information.	
Perceived risk	PR1	I am not worried about the health information on OHCs may mislead me.	Featherman and Pavlou (124)
	PR2	I am not worried about my physical health will be negatively affected.	
	PR3	I am not worried about experiencing a loss of energy, time, or financial resources.	
	PR4	I am not worried about others know about the disease I have and forming negative opinions about me.	
	PR5	I am not worried about my personal information being leaked or misused.	
Credibility discrimination ability	CDA1	When using OHCs, I check if the health information includes exaggerated or absolute statements.	Ivanitskaya et al. (125)

(Continued)

TABLE 1 (Continued)

Construct	Item labels	Items content	Source
	CDA2	When using OHCs, I check if the health information includes any persuasive language.	
	CDA3	When using OHCs, I check if the health information includes promotional or advertising content.	
	CDA4	When using OHCs, I check if the health information includes statements claiming to provide unique or confidential information.	
	CDA5	When using OHCs, I check if the health information includes a lot of negations statements in health information.	
Accuracy discrimination ability	ADA1	When using OHCs, I check if the health information includes punctuation errors.	Harris (126)
	ADA2	When using OHCs, I check if the health information includes improper spacing.	
	ADA3	When using OHCs, I check if the health information includes grammar errors.	
	ADA4	When using OHCs, I check if the health information includes one-sided viewpoints.	
	ADA5	When using OHCs, I check if the health information is complete.	
Reasonableness discrimination ability	RDA1	When using OHCs, I check if the health information includes statements that intentionally overstate the importance.	Li et al. (127)
	RDA2	When using OHCs, I check if the health information includes a lot of emotional tone or verbal judgments.	
	RDA3	When using OHCs, I check if the logic of the health information makes sense.	
	RDA4	When using OHCs, I check if the content of the health information is relevant to its title or topic.	
Support discrimination ability	SDA1	When using OHCs, I check if the numerical statistics in the health information have an accurate source.	Zhang (25)
	SDA2	When using OHCs, I check if the health information includes the link of source documentation.	
	SDA3	When using OHCs, I check if the health information is false authority.	
	SDA4	When using OHCs, I pay attention to the timeliness of health information.	

are urban residents. The largest proportion of the participants were corporate workers, accounting for 34.66%. More than half of the participants had a monthly income of 10,000 RMB or lower. The physical health status of most participants is "General," accounting for 34.96%. A total 40.00% of the participants indicated that they "Often" pay attention to health information. The highest proportion of participants (37.71%) reported using specialized online health websites, while 41.22% reported utilizing online health communities "5–6 times" per month.

4.2 Structural equation modeling analysis

4.2.1 Reliability and validity testing

The reliability of the scale was tested by SPSS25.0 of IBM, and the validity of the scale was analyzed by using Amos23.0. The results are shown in Tables 3, 4.

It can be seen that the Cronbach's Alpha varied from 0.869 to 0.914 for each construct (Table 3), exceeding the cut-off point of 0.70, demonstrating good scale reliability (99). The standardized loading values of all variables ranging from 0.771 to 0.839, exceeded the threshold of 0.6; the average variance extracted (AVE) of all latent variables was between 0.620 and 0.680, which is higher than 0.5; and the composite reliability (CR) values of all latent variables exceeded 0.7; confirming the satisfactory convergent validity of the scale (94). In Table 4, the values bold on the diagonal are the arithmetic square roots of the corresponding variables AVE. The values outside the diagonal indicate the correlation coefficients among the latent variables. According to the results, the arithmetic square root of AVE of all latent variables is higher than the correlation coefficients of the rows and columns in which they are located, which means that the discriminant validity among the latent variables is good (100).

4.2.2 Model fit testing

The collected sample data were imported into AMOS software, and a model diagram was constructed to the analysis of model fit. The criteria for evaluating each model fit were referred to the recommendations of Dou et al. (101). The results are shown in Table 5. The ratio of chi-square to degrees of freedom (X^2/DF) = 1.125, which is less than the recommended threshold of 3. The values of RMSEA, CFI, IFI, NFI, and GFI are 0.014, 0.992, 0.992, 0.930, and 0.920. All the fit indices are within the range of the recommended range, which indicates that the research model fits well with the collected data.

4.2.3 Hypothesis testing

The critical ratio (CR) value is the ratio of the parameter estimate to the parameter estimate standard error (SE). If the CR > 1.96, then the parameter estimate passes the test at the significance level $\alpha = 0.05$.

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TABLE 2 Demographic characteristics of participants.

Variables	Categories	Frequency (*N* = 655)	Percentage
Gender	Male	344	52.50%
	Female	311	47.50%
Age group	Below 18	65	9.93%
	18–40	232	35.42%
	41–65	199	30.38%
	66 and above	159	24.27%
Education level	Junior high school or below	96	14.65%
	Senior high school	130	19.85%
	Bachelor's degree	326	49.77%
	Master's degree or above	103	15.73%
Living area	Urban	487	74.40%
	Rural	168	25.60%
Occupation	Student	65	9.92%
	Government or State-owned enterprise employees	131	20.00%
	Private enterprise employees	227	34.66%
	Freelancer	30	4.58%
	Self-employed	65	9.92%
	Farming	26	3.97%
	Unemployed	29	4.43%
	Other	82	12.52%
Monthly income	Below 2000 RMB/month	95	14.50%
	2000–5000RMB/month	199	30.38%
	5,001–10000RMB/month	170	25.95%
	10,001–20000RMB/month	116	17.72%
	Above 20000RMB/month	75	11.45%
Health condition	Extremely poor	65	9.93%
	Relatively poor	87	13.28%
	General	229	34.96%
	Relatively good	164	25.04%
	Extremely good	110	16.79%
Attention to health information	Rarely	69	10.53%
	Sometimes	139	21.23%
	Often	262	40.00%
	Frequently	185	28.24%
Types of online health communities	Specialized online health websites (such as We Doctor, 39 Health, Haodaifu)	247	37.71%
	Health section of comprehensive websites (such as Health Section of Tencent Health and Bui Du)	144	21.98%
	Healthcare APP (such as DXY, Meet you)	161	24.58%
	Online health discussion groups (such as patient discussion QQ groups, WeChat groups)	103	15.73%
Frequency of using online health communities	1–2 times	66	10.08%
	3–4 times	135	20.61%
	5–6 times	270	41.22%
	7 or more times	184	28.09%

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TABLE 3 Reliability and convergent validity testing.

Constructs	Items	Standardized loadings	Cronbach's alpha	AVE	CR
Information quality(IQ)	IQ1	0.814	0.876	0.640	0.877
	IQ2	0.792			
	IQ3	0.799			
	IQ4	0.794			
Information source (ISE)	ISE1	0.774	0.869	0.625	0.870
	ISE2	0.787			
	ISE3	0.824			
	ISE4	0.777			
Informational support (IST)	IST1	0.804	0.878	0.643	0.878
	IST2	0.795			
	IST3	0.793			
	IST4	0.816			
Emotional support (ES)	ES1	0.809	0.884	0.655	0.884
	ES2	0.793			
	ES3	0.831			
	ES4	0.804			
Technological security (TS)	TS1	0.763	0.869	0.624	0.869
	TS2	0.799			
	TS3	0.791			
	TS4	0.805			
Technological facilitation (TF)	TF1	0.814	0.880	0.648	0.880
	TF2	0.820			
	TF3	0.792			
	TF4	0.793			
Self-efficacy (SE)	SE1	0.771	0.868	0.622	0.868
	SE2	0.783			
	SE3	0.784			
	SE4	0.817			
Perceived value (PV)	PV1	0.784	0.891	0.620	0.891
	PV2	0.785			
	PV3	0.807			
	PV4	0.785			
	PV5	0.776			
Perceived risk (PR)	PR1	0.839	0.914	0.680	0.914
	PR2	0.814			
	PR3	0.809			
	PR4	0.830			
	PR5	0.832			
Credibility discrimination ability (CDA)	CDA1	0.786	0.895	0.632	0.896
	CDA2	0.813			
	CDA3	0.786			
	CDA4	0.799			
	CDA5	0.793			

(Continued)

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TABLE 3 (Continued)

Constructs	Items	Standardized loadings	Cronbach's alpha	AVE	CR
Accuracy discrimination ability (ADA)	ADA1	0.823	0.902	0.649	0.902
	ADA2	0.796			
	ADA3	0.793			
	ADA4	0.818			
	ADA5	0.798			
Reasonableness discrimination ability (RDA)	RDA1	0.818	0.881	0.651	0.882
	RDA2	0.799			
	RDA3	0.801			
	RDA4	0.809			
Support discrimination ability (SDA)	SDA1	0.792	0.882	0.652	0.882
	SDA2	0.807			
	SDA3	0.809			
	SDA4	0.821			

TABLE 4 Discriminant validity testing.

	IQ	ISE	IST	ES	TS	TF	SE	PV	PR	CDA	ADA	RDA	SDA
IQ	0.800												
ISE	0.376	0.791											
IST	0.400	0.333	0.802										
ES	0.312	0.332	0.341	0.809									
TS	0.375	0.348	0.380	0.365	0.790								
TF	0.380	0.313	0.371	0.312	0.330	0.805							
SE	0.428	0.351	0.324	0.369	0.359	0.359	0.789						
PV	0.380	0.355	0.362	0.365	0.431	0.347	0.384	0.787					
PR	−0.049	−0.167	−0.049	−0.069	−0.052	−0.045	−0.041	−0.040	0.825				
CDA	0.402	0.389	0.384	0.373	0.427	0.388	0.407	0.468	0.056	0.795			
ADA	0.404	0.391	0.386	0.375	0.429	0.390	0.409	0.470	0.056	0.610	0.806		
RDA	0.351	0.340	0.336	0.326	0.373	0.339	0.356	0.409	0.049	0.530	0.533	0.807	
SDA	0.392	0.379	0.375	0.364	0.417	0.379	0.397	0.457	0.054	0.592	0.595	0.518	0.807

TABLE 5 Goodness-of-fit results.

Fit indices	X^2/DF	RMSEA	CFI	IFI	NFI	GFI
Recommended values	<3	<0.08	>0.9	>0.9	>0.9	>0.9
Model values	1.125	0.014	0.992	0.992	0.930	0.920

According to the C.R value and *p*-value shown in Table 6, among the 20 hypotheses, 17 hypotheses were found to be significant at $\alpha = 0.05$ level. While the remaining three hypotheses did not pass the test. The specific test results are as follows: The information source has a significant negative effect on perceived risk. The information quality, information source, informational support, emotional support, technological security, technological facilitation, and self-efficacy have a significant positive effect on perceived value. Information quality, information source, informational support, emotional support, technological security, technological facilitation, and self-efficacy have a significant positive effect on health information discernment abilities. Perceived value and perceived risk have a significant positive effect on health information discernment abilities. However, the hypothesis of the effect of information quality on perceived risk did not pass the test. The influence of self-efficacy on perceived risk is not significant. The influence of perceived risk on perceived value is also not significant (Figure 2).

TABLE 6 Hypothesis testing results of the research model.

Hypothesis	Path	Standardized coefficient	S.E.	C.R.	*P*	Result
H1a	IQ → PV	0.102	0.046	2.117	*	Support
H1b	IQ → PR	0.011	0.054	0.205	0.838	Not support
H1c	IQ → HIDA	0.110	0.034	2.582	**	Support
H2a	ISE → PV	0.105	0.046	2.278	*	Support
H2b	ISE → PR	−0.177	0.055	−3.556	***	Support
H2c	ISE → HIDA	0.168	0.035	4.061	***	Support
H3a	IST → PV	0.095	0.044	2.042	*	Support
H3b	IST → HIDA	0.110	0.033	2.683	**	Support
H4a	ES → PV	0.118	0.042	2.627	**	Support
H4b	ES → HIDA	0.110	0.031	2.763	**	Support
H5a	TS → PV	0.203	0.043	4.304	***	Support
H5b	TS → HIDA	0.170	0.033	3.995	***	Support
H6a	TF → PV	0.093	0.042	2.053	*	Support
H6b	TF → HIDA	0.143	0.031	3.542	***	Support
H7a	SE → PV	0.124	0.043	2.620	**	Support
H7b	SE → PR	0.017	0.052	0.329	0.742	Not support
H7c	SE → HIDA	0.138	0.033	3.256	***	Support
H8	PR → PV	0.013	0.034	0.334	0.738	Not support
H9	PV → HIDA	0.250	0.036	5.780	***	Support
H10	PR → HIDA	0.147	0.026	4.299	***	Support

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

4.3 Fuzzy-set qualitative comparative analysis

4.3.1 Data calibration

To categorize the sample data into different set affiliations, a data calibration operation must be performed on the questionnaire data before the configuration analysis. In this study, a 5-point Likert scale was chosen for the design of the measurement questionnaire, which had to be transformed into an affiliation scale between 0 and 1 (102). By calculating the mean value of the measurement items as the original data of each variable. fsQCA4.1 software was used to calibrate the integrated data, with anchor points set at (0.95, 0.5, 0.05), which means that 95% of the set is fully affiliated, 50% is the maximum fuzzy affiliation point, and 5% is not affiliated at all (103).

4.3.2 Necessary analysis of single conditions

A single condition necessity test was carried out on the outcome variables, so as to explore whether there is a single necessary condition variable that leads to the outcome. It is generally considered that consistency >0.9 can be regarded as a necessary condition. The results are shown in Table 7. It can be seen that the consistency of Information Quality (IQ), Information Source (ISE), informational support (IST), Emotional Support (ES), Technological Security (TS), Technological Facilitation (TF), Self-Efficacy (SE), Perceived Value (PV), and Perceived Risk (PR) was <0.9, which indicates that the explanatory power of these nine single elements on the outcome variables is weak. They did not have a dominant influence on health information discernment abilities. Further exploration is needed to examine the sufficiency of the effects of configurations on the outcome.

4.3.3 Sufficiency analysis of configurations

The truth table was constructed based on the calibrated fuzzy set data table. The consistency threshold is set to 0.80. The case threshold is set to 3. The PRI consistency threshold is set to 0.75 (104). Typically, three kinds of solutions are generated after analyzing through fsQCA4.1: complex solutions, intermediate solutions, and parsimonious solutions. The parsimonious solutions and the intermediate solutions can effectively balance the discrepancy between theory and facts (105). Thus, this study combined the parsimonious solutions and the intermediate solutions as the analysis results. The condition variables are distinguished into core conditions and peripheral conditions through qualitative comparative analysis. There are 10 specific condition variable combination paths, which are divided into four types, as shown in Table 8.

According to Table 8, the consistency of the configurations ranges from 0.991 to 0.995, and the solution consistency level of the health information discernment abilities is 0.976, with a solution coverage of 0.574. This indicates that the collection of these 10 paths has a strong explanatory power of the health information discernment abilities. It is able to explain 57.4% of the results of the sample. By categorizing configurations with the same core conditions, four types of configuration patterns for health information discernment can be identified as follows:

1. Configuration S1: This configuration consists of two sub-configurations (S1a, S1b). The common core conditions are high information sources and high informational support. Common peripheral conditions are high information quality, high emotional support, high self-efficacy, and high perceived

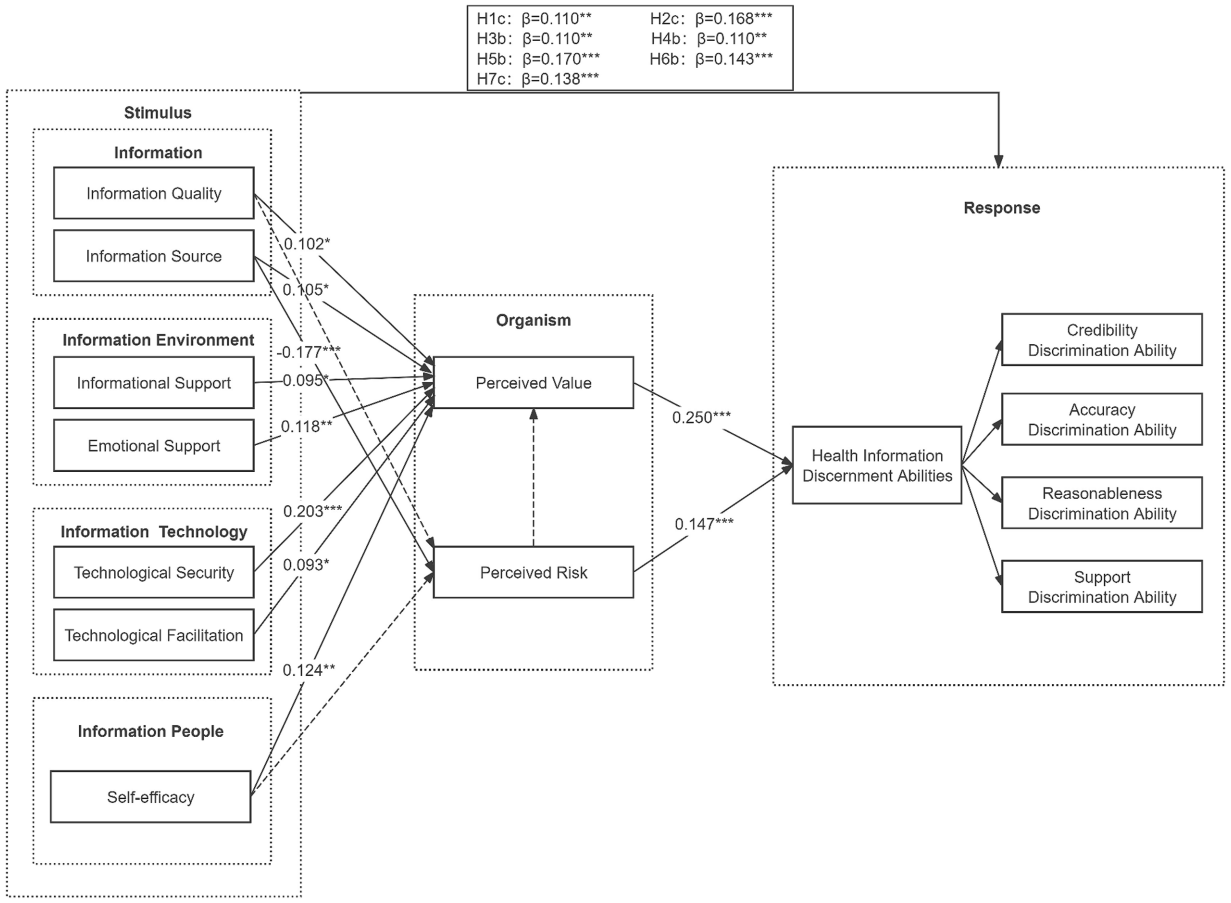

FIGURE 2
Research model of hypothesis testing. Solid arrows indicate having a significant impact, while dashed arrows represent the absence of an impact.

value. In addition to these shared core and peripheral conditions, when there is high technological security, or high technological facilitation and low perceived risk coexist, both situations can trigger the generation of high health information discernment abilities.

2. Configuration S2: This configuration consists of two sub-configurations (S2a, S2b).The common core conditions are high technological security and technological facilitation. Common peripheral conditions are high information quality, high emotional support, high self-efficacy, and high perceived value. In addition to these shared core and peripheral conditions, when there is high informational support, or high information sources and low perceived risks coexist, both situations can trigger the generation of high health information discernment abilities.
3. Configuration S3: This configuration consists of four sub-configurations (S3a, S3b, S3c, S3d). The shared core conditions are high information source, high informational support, high technological security, and high technological facilitation. Comparing S3a and S3d, we found that the shared peripheral conditions are high information quality and high emotional support. When there is a high perceived value or the coexistence of high self-efficacy and high perceived risk, both situations can trigger high health information discernment abilities. Comparing S3b and S3c, we found that the shared peripheral conditions are high self-efficacy, high perceived value, and low perceived risk. When both the shared core and peripheral conditions are present, high information quality or high emotional support triggers high health information discernment abilities, suggesting a substitutable relationship between information quality and emotional support.
4. Configuration S4: This configuration includes two sub-configurations (S4a, S4b). The shared core conditions are high information source, low technological security, low technological facilitation, and high perceived risk. The shared peripheral conditions are low information quality, low self-efficacy, and high perceived value. Comparing S4a and S4b, we found that when both the shared core and peripheral conditions are present, high informational support or high emotional support triggers high health information discernment abilities, indicating a substitutable relationship between informational support and emotional support.

In summary, it can be seen from the 10 sub-configurations that while nine antecedent conditions all appear in the same configuration at the same time. These configurations contain at least two influencing factors. It shows that the health information discernment abilities of OHCs users are not caused by a single influencing factor but rather by

the interdependence of multiple factors. There are multiple configurations that can lead to the target results. Traditional SEM studies cannot explain the complex relationship between these factors and outcomes.

TABLE 7 Results of single conditions necessity testing.

Antecedent variables	Outcome variable	
	HIDA	
	Consistency	Coverage
IQ	0.790	0.822
~IQ	0.506	0.746
ISE	0.788	0.811
~ISE	0.504	0.755
IST	0.787	0.812
~IST	0.507	0.756
ES	0.780	0.814
~ES	0.505	0.741
TS	0.782	0.832
~TS	0.521	0.745
TF	0.780	0.821
~TF	0.512	0.742
SE	0.790	0.822
~SE	0.504	0.742
PV	0.829	0.827
~PV	0.474	0.744
PR	0.626	0.797
~PR	0.659	0.771

4.3.4 Robustness testing

The robustness testing is necessary to ensure that the findings are generalizable. Schneider and Wagemann (106) proposed feasible ways of robustness testing, such as by adjusting the data calibration thresholds and the consistency thresholds, and by changing the frequency of cases. In this study, the consistency threshold was changed from 0.8 to 0.85. It was found that the parameter adjustments did not result in any changes in the configuration paths as well as in the fit parameters for consistency and coverage. Thus, the analysis outcomes was found to be relatively robust.

5 Discussion

5.1 Main findings

1. The four dimensional factors of information (information quality, information source), information environment (informational support, emotional support), information technology (technological security, technological facilitation), and information people (self-efficacy) all have significant positive effects on health information discernment abilities. As with previous studies, online health communities are interlocking information systems. The information activities of users cannot be separated from the influences of all four factors: health information, community environment, information technology, and community users (107). From the viewpoint of information factors, high-quality information resources save users the energy and time needed for information screening, and authoritative information sources are more convincing to users (108). In terms of the information environment, the strong informational support of the community platform facilitates the efficient delivery of online

TABLE 8 Results of configuration analysis.

Antecedent Variables	S1(ISE*IST)		S2(TS*TF)		S3(ISE*IST*TS*TF)				S4(ISE* ~ TF*PR)	
	S1a	S1b	S2a	S2b	S3a	S3b	S3c	S3d	S4a	S4b
IQ	•	•	•	•	•	•		•	⊗	⊗
ISE	●	●		•	●	●	●	●	●	●
IST	●	●	•		●	●	●	●	●	⊗
ES	•	•	•	•	•		•	•	⊗	•
TS	•		●	●	●	●	●	●	⊗	⊗
TF		•	●	●	●	●	●	●	⊗	⊗
SE	•	•	•	•		•	•	•	⊗	⊗
PV	•	•	•	•	•	•	•		•	•
PR		⊗		⊗		⊗	⊗	●	●	●
Raw coverage	0.441	0.342	0.439	0.343	0.433	0.345	0.342	0.314	0.182	0.188
Unique coverage	0.022	0.011	0.024	0.011	0.014	0.014	0.009	0.008	0.008	0.011
Consistency	0.991	0.995	0.992	0.995	0.994	0.993	0.992	0.995	0.993	0.991
Solution consistency	0.976									
Solution coverage	0.574									

"●" indicates that the core conditions exist. "⊗" indicates that the core conditions absent. "•" indicates that the peripheral conditions exist. "⊗" indicates that the peripheral conditions absent. Blank space indicates that the conditions can exist or not.

health information and increases users' health knowledge, while sufficient emotional support helps users to relieve anxiety and get inspired. From the viewpoint of information technology, information technology links users with the community environment. The assistance of advanced information technology makes the community function perfectly and enriches the user experience, thus improving the efficiency of users in identifying health information. Technological security also guarantees that the privacy of users is protected (109). From the viewpoint of the information people, the user is the crucial element in the entire health information discernment process. The user's health knowledge reserve, information searching skills, and information evaluation ability all reflect the user's self-efficacy (110). When the user's self-efficacy is higher, it is easier to obtain true and effective health information. Analyzing from the perspective that information ecological elements such as information, information environment, information technology, and information people fit together can more comprehensively and deeply analyze the influencing factors of health information discernment abilities.

2. Perceived value and perceived risk positively influence users' health information discernment abilities. However, perceived risk does not influence perceived value. The path coefficients of perceived value and perceived risk on health information discernment abilities are 0.250 and 0.147, respectively, with $p < 0.001$. This indicates that perceived value and perceived risk have a significant influence on health information discernment abilities, with perceived value having a much greater effect than perceived risk. On the one hand, when users engage in health information discernment, they weigh the trade-off between value and risk. Higher value perception encourages users to seek out health information, while higher risk perception leads them to avoid it (111). In the process of judging the value and risk of health information, users' health literacy improves continuously, leading to enhanced health-related knowledge and cognitive skills, which in turn bolster their discernment abilities. On the other hand, it is believed that users' primary motivation for discerning health information is to obtain information that aligns with their personal needs and health goals (112). Compared with perceived risk, users place more importance on the value they can obtain after discerning health information. Thus, perceived value plays a greater role, weakening the influence of perceived risk.
3. The effect of information quality on perceived risk is not significant. However, information quality has a significant positive influence on perceived value and health information discernment abilities. Consistent with the results of fsQCA analyses, in configuration S3d, high information quality promotes high health information discernment abilities when high information quality is used as a peripheral condition and high perceived risk is used as a core condition. In configurations S1, S2, S3a, and S3b, high information quality and high perceived value, as both peripheral conditions, can lead to the generation of high health information discernment abilities. This May be because most of the types of health communities used by the users in this study were from professional online health websites, such as Seeking Medicine, We Doctor, and Haodaifu. For users, compared to other online health information exchange zones or groups, such as health discussions on Sina Weibo, health information obtained through professional health websites is more medically authoritative and instructive (113). Users have sufficient trust in professional health websites, thus it will not have an impact on their risk perception. However, it will be convenient for users and increase their perceived value.
4. Self-efficacy does not have a significant effect on perceived risk, but it does have a significant positive effect on perceived value and health information discernment abilities. In configuration S3d, high self-efficacy as a peripheral condition and high perceived risk as a core condition can lead to high health information discernment abilities. In configurations S1, S2, S3b, and S3c, high self-efficacy and high perceived value were both used as peripheral conditions that could lead to high health information discernment abilities. The results of the survey showed that 65.50% of the participants had a bachelor's degree or above. The higher the education level of the users, the more health information discernment skills they master, which encourages they to quickly obtain high-value information. When users have acquired a sufficient amount of health knowledge through reliable sources and are self-assured in their understanding, they are better equipped to assess and navigate risky health information effectively (114). They rely on their solid foundation of health knowledge to critically evaluate the provided information, enabling them to avoid falling victim to any potential health risks or misinformation. Their confidence empowers them to make informed Decisions about their wellbeing, carefully considering the credibility and validity of the health information they encounter, and subsequently taking appropriate actions to safeguard their health and avoid potential harm (115). In terms of age distribution, the 18–40-years-old group has the largest proportion, and they are full of hope for the future, positive and optimistic, and usually have a lower propensity to perceive risk.
5. There are 10 antecedent configurations affecting users' ability to screen health information, categorized into 4 types. The core conditions of configuration S1 are high information source and high informational support. For configuration S2, the core conditions are high technological security and high technological facilitation. The core conditions of configuration S3 are high information source, high informational support, high technological security, and high technological facilitation. The core conditions of configuration S4 are high information source, low technological facilitation, and high perceived risk. The four types of configurations illustrate that information source, informational support, technological security, technological facilitation, and perceived risk are the core conditions affecting users' health information discernment abilities. Additionally, information quality, emotional support, self-efficacy, and perceived value appeared several times as peripheral conditions; further supporting the fact that they significantly affect users' health information discernment abilities.

In addition, the consistency and coverage of S1, S2, and S3 were higher than that of S4. It is because the components of S1, S2, S3b, S3c, and S3d all contained the factors of information, information

environment, information technology, and information people. While the component of S3a contained the factors of information, information environment, and information technology. In contrast, configuration S4 only includes information and information environment factors. This further confirms the applicability of the information ecology theory in online health communities, where the triggering of high health information discernment abilities requires a combination of information factors such as information, information environment, information technology, and information people, rather than a single factor.

Although perceived value has the greatest effect on health information discernment abilities in the SEM single-factor analysis. It is a peripheral condition in all four configurations, which suggests that it does not play a significant role when combined with other factors. This finding compensates for the limitations of SEM in examining the net benefit of a single factor.

5.2 Theoretical significance and practical implications

Theoretically, this study applied the stimulus-organism-response theory, information ecosystem theory, and the Mindsponge theory to the field of health information discernment abilities research, providing rich and solid theoretical support for health information discernment abilities research. The study considered the online health community as an information ecosystem, which extends the research perspective on health information discernment abilities. In addition, this study attempted to apply a combination of questionnaire survey and fsQCA methods to the study of health information discernment abilities. Previous studies have mainly used the experimental method or interview method, and seldom used the fsQCA method. This study expanded the applicability of the fsQCA method and enriched the research method system of users' health information discernment abilities.

Practically, it provides a reference for improving users' health information discernment abilities. From the information perspective, it is necessary to strengthen the construction of information resources in online health information communities, raise the threshold of information release, and set community norms to constrain users to ensure the circulation of high-quality information resources and cut off the sources of poor-quality health information. At the same time, it is necessary to encourage more professional doctors, medical researchers, and health experts to join the community to provide users with accurate health information. From an information environment perspective, attention should be paid to users' needs and understanding of users' interests and preferences, so as to provide personalized services and enhance user engagement. Establishing channels for friendship and mutual assistance, so that users can communicate freely in the community, fostering strong friendships among users, thus increasing their sense of belonging and affiliation to the community. From an information technology perspective, it is necessary to increase the strength of information review and information regulation to detect and deal with false or harmful information on time. Online health communities should provide users with information screening tools and reliable information resources, such as guidance on assessing the credibility of websites and recommending authoritative health websites and applications. From a user perspective, users' health information literacy education should be strengthened. Training and education courses on health information discrimination should be provided to users to improve their sense of self-efficacy.

6 Conclusion

This study explored the factors influencing health information discernment abilities and the configuration paths. From the results of the SEM analysis, it was found that information quality, information source, informational support, emotional support, technological security, technological facilitation, self-efficacy, perceived value, and perceived risk all have a positive effect on health information discernment abilities. Improvement in health information discernment abilities requires a combination of factors, not just a single element. The 10 paths analyzed by fsQCA contain a minimum of two dimensional factors in each combination of information, information environment, information technology, and information people. fsQCA supplements the exploration of relationships between multiple variables, complementing the SEM approach. The combined application of the two methods should be promoted. This study hopes to provide experiences and references for online health community information service, information resource construction, and users' health information discernment abilities development.

7 Limitations

The primary data of this study were mainly derived from people using online health communities in China, which lacked an exploration of multiculturalism. User information behaviors and cultural practices May be different in other countries or regions. Future studies May consider sending questionnaire emails to users in different countries to obtain data. In addition, it is difficult to avoid subjective bias and the influence of the environment in which the questionnaires are completed. In future studies, empirical analyses could be conducted in conjunction with data crawled from online health communities or user interviews. The primary demographic for this survey was the youth, with an uneven distribution across other age groups. However, as the influence of online health communities continues to grow, people of different age groups are increasingly paying attention to these platforms. In the future, with sufficient time and resources, the sample survey range can be expanded to study the health information discernment abilities of users across different demographic groups.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Institutional Review Board of College of Life Sciences, Central South University (Reference no. 2023-1-34). The studies were conducted in accordance with the local legislation and institutional requirements. The

participants provided their written informed consent to participate in this study.

Author contributions

CW: Formal analysis, Investigation, Methodology, Writing – original draft. YC: Formal analysis, Methodology, Writing – original draft. JL: Supervision, Writing – review & editing. YG: Supervision, Writing – review & editing. XW: Data curation, Investigation, Project administration, Writing – review & editing. XH: Data curation, Investigation, Writing – review & editing. DH: Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Current status of short video as a source of information on lung cancer: a cross-sectional content analysis study

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Background: The morbidity and mortality rates of lung cancer continue to rise, leading to a significant disease burden. Health education on lung cancer serves as an effective approach for prevention and treatment. With the increasing popularity of the Internet, an escalating number of patients are turning to video platforms for health information. Short videos facilitate better absorption and retention of information, thus becoming the primary channel for health education communication. However, the quality of information provided in videos on these platforms remains uncertain. Therefore, this study aims to assess the information quality pertaining to lung cancer in short videos available on a Chinese video platform.

Methods: Lung cancer-related videos on two short video platforms (TikTok and Kwai) were screened, and only Chinese (Mandarin) videos were included. The Global Quality Score (GQS) and modified DISCERN (mDISCERN) tools were then used to evaluate the quality and reliability of the information. A comparative analysis was conducted on videos from various sources. Additionally, correlation analysis was employed to investigate the factors influencing video quality.

Results: After screening, a total of 186 videos were included. The median GQS score and mDISCERN score were 3 (IQR: 3-4) and 2 (IQR: 2-4), respectively. A total of 44.1% of the lung cancer videos provided a comprehensive explanation of the symptoms, while only 3.2% fully explanation the complications associated with lung cancer. Health professionals, particularly specialists, demonstrated higher quality video information compared to individual users (P<0.001). The correlation coefficient between GQS score and mDISCERN score was 0.340, showing a significant positive correlation (P<0.001). In addition, GQS score was positively correlated with video duration (r=0.177, P=0.015)

Conclusion: The information quality of the 186 videos screened by the two platforms in this study was generally unsatisfactory. However, videos provided by experts were deemed relatively reliable, with video duration being closely associated with information quality. Therefore, it is crucial to meticulously screen high-quality and dependable videos on the platform in order to effectively guide lung cancer prevention and treatment.

KEYWORDS

lung cancer, short video, health information, health education, medical knowledge

Introduction

The prevalence of lung cancer, a highly aggressive disease, exerts a significant impact on the escalating burden of cancer-related mortality worldwide (1–3). In 2020 alone, there were 2.2 million newly diagnosed cases and 1.8 million reported deaths attributed to this condition (1). The latest epidemiological studies conducted in Europe indicate that lung cancer accounts for 20% of all deaths in the region, with a persistently increasing mortality rate observed among the elderly population (2). The trend of cancer burden in China from 2005 to 2020 revealed that trachea, bronchus, and lung cancer had the highest mortality rate among males, reaching 75.5 per 100,000 (3). The incidence and mortality rates of lung cancer exhibit significant variations across different regions worldwide, with countries characterized by higher levels of economic development, as measured by the Human Development Index (HDI), experiencing three to four times greater incidence and mortality rates (1, 4). These variations can be attributed to factors such as tobacco consumption patterns, gender disparities, and divergent economic trends (5).

The mortality rate of lung cancer in developed countries has witnessed a decline in recent years, primarily attributed to the implementation of tobacco control measures, enhanced screening programs, and improved treatment options (1). In low- and middle-income countries, there exist both patient-related barriers and obstacles within national healthcare systems (4). Apart from limited accessibility to state-of-the-art therapies for lung cancer, primary healthcare professionals lack sufficient knowledge regarding the latest screening guidelines (6). Lung cancer screening guidelines mainly use low-dose-computed-tomography (LDCT), followed by bronchoscopy and sputum screening. The latest screening protocols include artificial intelligence-assisted CT examination and liquid biopsy (7). Patients themselves may also exhibit inadequate awareness about lung cancer, a lack of understanding regarding the benefits of early screening, and possess fatalistic views towards this disease (8, 9). Therefore, a comprehensive understanding of the etiology of lung cancer, early screening methods, and standardized treatment can significantly enhance patients' survival rates.

The reform of information technology is impacting people's daily life in various ways. It also offers patients effective health communication methods, enabling them to access relevant disease management information and empowering them with disease management capabilities (10). Visual information platforms, such as TikTok and Kwai, offer more visually appealing image and video content that facilitates patients' comprehension and retention of information. Several studies (11–14) have examined health-related information available on these platforms, including chronic obstructive pulmonary disease (COPD), inflammatory bowel disease (IBD), and cancer. These studies have found that patients are more inclined to accept and remember visually engaging relevant information (15, 16). In addition, there is evidence (17, 18) that active use of the visual information platform is associated with a good prognosis of patients, the platform helps patients with self-disease management, and reduces the psychological burden of patients. However, short video platforms can lead to the rapid spread of false health-related information, which can mislead patients' disease management decisions and even pose a threat to their lives. Health information on the Internet is often complex and challenging for non-professionals to comprehend, especially for individuals with limited health literacy. A study (19) revealed that over half of COPD patients encountered difficulties in discerning between high- and low-quality health information online. Therefore, it is crucial to assess the credibility of image-based information platforms and guide lung cancer patients towards standardized disease management protocols in order to reduce lung cancer mortality rates.

Previous studies have evaluated the quality of health information of several diseases on TikTok (20–22), but the quality of lung cancer short video information is still unclear. In order to improve the information content of lung cancer short video and guide the disease management of lung cancer patients, this study will examine the quality of lung cancer information on domestic short video platforms and evaluate the quality of lung cancer related health information.

Methods

Data collection

Between April 6, 2024 and April 7, 2024, we conducted a cross-sectional study. In this study, the Chinese keyword "lung cancer" was used to search for related videos on the two most popular short video sharing platforms in China (TikTok and Kwai), and the default top 100 videos were screened. Videos that met the following criteria were excluded from the analysis: 1) repetitive videos; 2) silent videos and 3) videos that were unrelated to the topic. The video was screened by two respiratory doctors (Xinyu Zhao and Xinyi Yao), and the content and quality of the video were independently reviewed. The data were recorded in Excel (Microsoft Corporation) and it was agreed that a third senior respiratory specialist (Binbin Sui) would conduct a negotiated assessment of the disputed issues. The following video information was collected: the platform of videos, the source of videos, the identity authentication of the publisher, date of publication, departments of the medical worker, duration of videos, the number of likes, comments and collections, the content and the quality of the videos. The data of this study are publicly available and no ethical statement is required.

Assessment of video information's quality and reliability

All searches were conducted on a public computer, all Settings and history on the computer were deleted before the search is conducted, and cookies were disabled during the search process to avoid affecting the data. The Global Quality Score (GQS) and the modified DISCERN (mDISCERN) tool were utilized for assessing the information quality and reliability of videos, respectively. The GQS is a widely used video scoring tool to assess the informational quality of a video and consists mainly of five criteria ranging from 1 (poor quality) to 5 (high quality), with higher scores indicating higher

quality, as detailed in Supplementary Table 1 (23, 24). The reliability of health-related content was evaluated using the mDISCERN tool (11, 25). The instrument consists of five questions (Supplementary Table 2) that are scored on the basis of a "yes" or "no" response, with a minimum score of 0 and a maximum score of 5. At the same time, we also assessed the video content and employed an additional scoring tool to evaluate seven key aspects of lung cancer videos, encompassing epidemiology, etiology, symptoms, diagnosis, treatment, prevention, and complications. The scoring system was categorized into three levels: no inclusion (0 points), partial elucidation (1 point), and full explanation (2 points). Specialists include doctors in respiratory, thoracic surgery and oncology, while non-specialists mainly include doctors in other departments such as dermatology and gastroenterology.

Statistical analysis

Continuous variables were expressed as mean ± standard deviation (SD) or median and interquartile range (IQR) depending on whether they followed a normal distribution, and the Student's t test or Mann-Whitney U test was used to analyze the data. Categorical variables were presented in frequency and percentage, and Chi-square tests or Fisher exact tests were used. The Pearson correlation coefficient was calculated to evaluate the correlation between different scores and video features. Cohen's kappa coefficient was used to assess the consistency of the scores of two independent reviewers. Statistical analysis and plotting were performed using SPSS version 26.0 (IBM; Chicago, IL, USA) and R statistical software version 4.3.1 (www.r-project.org). P value < 0.05 was considered to indicate statistical significance.

Results

Short video features

The video platforms TikTok and Kwai are widely regarded as the two most famous platforms in China. After carefully screening the top 100 comprehensive video messages on two platforms, we eliminated duplicate, silent, and irrelevant content, and ultimately selected 186 short video messages (Figure 1). We have classified the sources of videos into three categories: specialists, non-specialists and individual users. Out of these videos, 71% were uploaded by professionals, 22.6% by non-professionals, and 6.4% by individual users. The median video duration was 72 seconds (Interquartile range [IQR]:21-101), the median number of likes and collections was 633(IQR:173-4010) and 132(IQR:28-636), respectively, and the median number of comments received was 58(IQR:13-343). The median completeness score was 6(IQR:5-8), the median GQS was 3

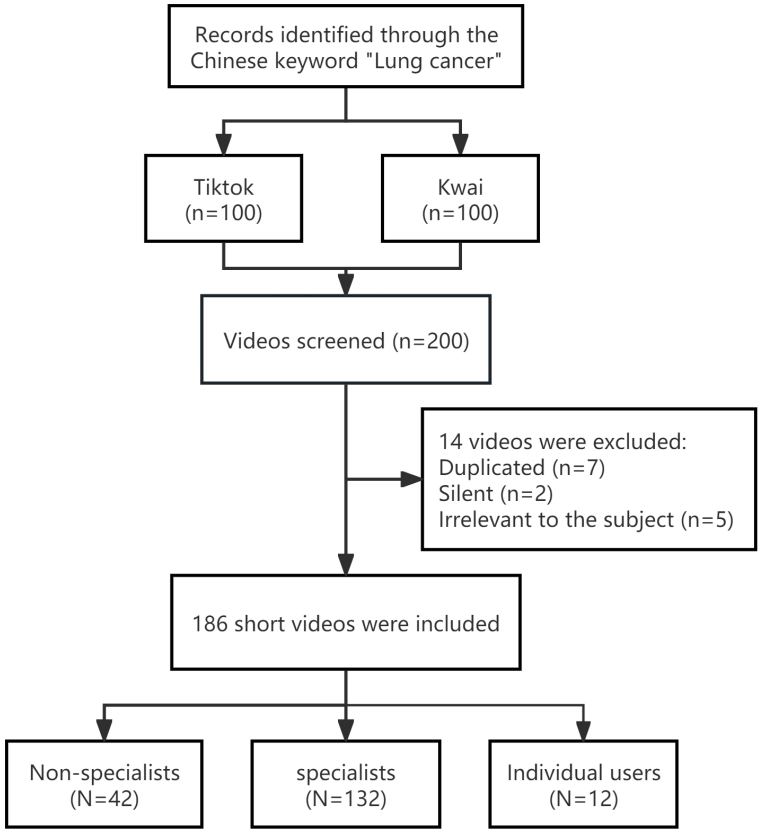

FIGURE 1
Lung cancer related videos were included in the flow chart.

(IQR:3-4), and the median mDISCERN score was 2(IQR:2-4) (Table 1). The quality assessment revealed that the lung cancer video information on the platform exhibited a low level of quality.

Short video content

We classified the completeness of the video content into seven aspects, encompassing epidemiology, etiology, symptoms, diagnosis, treatment, prevention, and complications associated with lung cancer. As shown in Figure 2, most of the videos comprehensively described the typical symptoms associated with lung cancer (44.1%), however, only a few videos introduced the complications of lung cancer (3.2%). Moreover, only a subset of the video full explanation the remaining 5 aspects of lung cancer. Among them, a mere 5.4% of the videos provide an in-depth explanation of the epidemiology of lung cancer, while 22.5%, 38.7%, and 12.7% of the videos respectively delve into the etiology, diagnosis, and treatment of this disease. (Table 2).

Short video source analysis

In addition, we conducted a comparative analysis of the videos on both platforms and observed that TikTok exhibited significantly higher engagement metrics in terms of likes (median: 1706 vs 209, $P<0.001$), comments (median: 173 vs 29, $P<0.001$), and collections (median: 290 vs 49, $P<0.001$) compared to Kwai. Conversely, Kwai demonstrated superior video completeness when compared to TikTok. However, both platforms displayed similar scores in terms of video quality (mDISCERN scores, median:2 vs 2, $P=0.131$) (Table 3). We conducted a further analysis of videos from various sources and observed that the quality of video information shared by healthcare professionals surpassed that posted by individual users. Notably, specialists exhibited significantly higher quality scores compared to non-specialists (mDISCERN scores, median: 3 vs 2, $P<0.001$) (Table 4). The Cohen's kappa values for GQS and the mDISCERN were 0.921 and 0.893, respectively, indicating a good agreement between the scores of the two independent reviewers. The correlation between the quality score of the video and its video features is simultaneously examined. As depicted in Table 5, the correlation coefficient between GQS score and mDISCERN score was 0.340, showing a significant positive correlation ($P<0.001$). In addition, GQS score was positively correlated with video duration (r=0.177, $P=0.015$). However, the GQS score was not significantly correlated with the number of likes, favorites, and comments. The violin plot, (Figure 3), also shows the consistent trend observed. In addition, the information quality scores of the two platforms were not evenly distributed, with a higher proportion of videos with lower scores. It is worth noting that most videos with mDISCERN scores exceeding 3 points were uploaded by specialists.

TABLE 1 Characteristics of 186 lung cancer related-short videos on TikTok and Kwai in China in 2024.

Characteristic		N=186
Short-video sharing platforms [n(%)]		
	TikTok	95 (51.1)
	Kwai	91 (48.9)
Video source [n(%)]		
	Non-specialists	42 (22.6)
	Specialists	132 (71.0)
	Individual user	12 (6.4)
Number of likes [median(IQR)]		633 (137-4010)
Number of comments [median(IQR)]		58 (13-343)
Number of collections [median(IQR)]		132 (28-636)
Video duration [s, median(IQR)]		72 (21-101)
Completeness score [median(IQR)]		6 (5-8)
GQS scores [median(IQR)]		3 (3-4)
mDISCERN scores [median(IQR)]		2 (2-4)

N,nubmer; IQR,interquartile range; GQS, Global Quality Score; mDISCERN, modified DISCERN.

Discussion

The visual social platform has gained popularity and demonstrated its advantages in disseminating health knowledge (15, 16). Video platforms replace traditional text-based information with visually appealing content, facilitating easier processing and retention of information for individuals (12, 26, 27). Moreover, the incorporation of health-related content evokes emotional responses and motivates individuals to engage in proactive health behaviors (28). As a highly prevalent and fatal malignant tumor in China, lung cancer imposes a substantial disease burden on the country's healthcare resources (5). The mortality rate associated with lung cancer continues to rise, particularly in rural areas characterized by low health literacy levels (29, 30), and short video platforms are the most suitable tools for health communication and education. The assurance of video information quality remains a primary concern for these platforms, given the varying levels of information accuracy and potential dissemination of biased or misleading content.

The information quality of the 186 videos screened by the two platforms in this study was generally unsatisfactory. While most videos provided comprehensive presentations on symptoms of lung cancer, there was a lack of coverage on the epidemiology, etiology, diagnosis, and treatment of lung cancer, particularly regarding complications. Notably, almost half of the videos failed to mention any lung cancer-related complications. One potential explanation is that individuals may excessively focus on the direct respiratory symptoms associated with lung cancer, while overlooking the potential impact of lung cancer on other bodily systems, such as the digestive system, endocrine system, and circulatory system. 40.3% of the videos mentioned the prevention of lung cancer, including screening programs such as CT and bronchoscopy. 38.7% of the videos had a detailed explanation of the treatment of lung cancer, and only 17.2% of the videos did not mention the treatment of lung cancer. However, none of the videos mentioned post-chemotherapy/

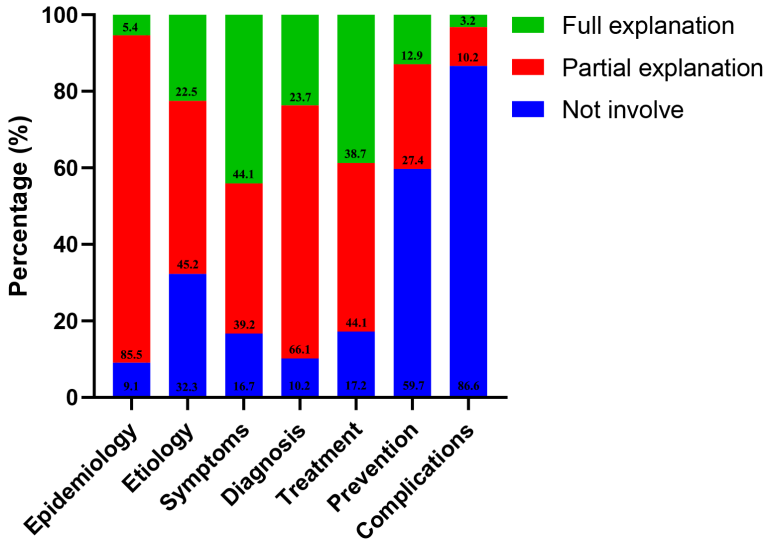

FIGURE 2
Percentage of videos involving content for each lung cancer.

radiotherapy and post- surgical care, which may need to be mentioned in future popular science videos.

In the process of video analysis, we observed distinct disparities in the characteristics between videos on the TikTok and Kwai platforms. Interestingly, TikTok videos exhibited significantly higher engagement metrics such as likes, shares, and comments compared to those on Kwai platform. Moreover, there was a discernible discrepancy in terms of video completeness favoring Kwai over TikTok. This disparity may be attributed to TikTok's predominant popularity among younger demographics resulting in a relatively lower emphasis on video quality but higher transmission rates. The comparison of video information from various user sources revealed that more than half of the videos were contributed by experts, indicating a higher reliability in video information compared to non-experts and individual users. These findings align with previous studies conducted on the YouTube platform (31, 32). However, it is worth noting that certain videos exhibit subpar information quality. Consequently, we recommend implementing content screening measures and enhancing the informational integrity of health-related videos on this platform to ensure effective lung cancer prevention and management while reducing its incidence and mortality rates. The correlation analysis revealed that there was no significant association between the quality of the video and the number of likes, favorites, and comments from the

TABLE 2 Completeness of 186 lung cancer related-short videos content on TikTok and Kwai in China in 2024.

Video content	Not involve (0 points)	Partial explanation (1 point)	Full explanation (2 points)
Epidemiology, n (%)	17 (9.1)	159 (85.5)	10 (5.4)
Etiology, n (%)	60 (32.3)	84 (45.2)	42 (22.5)
Symptoms, n (%)	31 (16.7)	73 (39.2)	82 (44.1)
Diagnosis, n (%)	19 (10.2)	123 (66.1)	44 (23.7)
Treatment, n (%)	32 (17.2)	82 (44.1)	72 (38.7)
Prevention, n (%)	111 (59.7)	51 (27.4)	24 (12.9)
Complications, n (%)	161 (86.6)	19 (10.2)	6 (3.2)

n,nubmer; IQR,interquartile range; GQS, Global Quality Score; mDISCERN, modified DISCERN.

TABLE 3 Comparison of 186 lung cancer related-short videos in different short-video sharing platforms in China in 2024.

Variables	TikTok (N=95)	Kwai (N=91)	p valve
Video source [n(%)]			0.118
Non-specialists	17 (66.7)	25 (62.5)	
Specialists	75 (14.3)	57 (27.3)	
Individual user	8 (4.7)	4 (1.1)	
Video duration [s, median(IQR)]	76(53-100)	72(48-101)	0.344
Number of likes [median(IQR)]	1706 (696-6526)	209 (56-943)	<0.001
Number of comments [median(IQR)]	173 (32-778)	29 (6-118)	<0.001
Number of collections [median(IQR)]	290 (84-1486)	49 (10-182)	<0.001
Completeness score [median(IQR)]	5 (4-7)	7 (5-8)	0.005
GQS scores [median(IQR)]	3 (3-4)	3 (2-4)	0.064
mDISCERN scores [median(IQR)]	2 (2-4)	2 (2-3)	0.131

n,nubmer; IQR,interquartile range; GQS, Global Quality Score; mDISCERN, modified DISCERN.

TABLE 4 Comparison of 186 lung cancer related-short video in different video source in China in 2024.

Variables	Non-specialists (N=71)	Specialists (N=148)	Individual user (N=9)	p valve
Number of likes [median(IQR)]	594 (107-4172)	667 (137-3778)	984 (156-10052)	0.789
Number of shares [median(IQR)]	45 (10-276)	58 (13-334)	88 (20-1350)	0.680
Number of collections [median(IQR)]	164 (23-1374)	120 (25-560)	194 (40-611)	0.850
Completeness score [median(IQR)]	6 (5-8)	6 (5-7)	4.5 (4-7)	0.073
GQS scores [median(IQR)]	3 (2-4)	3 (3-4)	2 (2-3)	<0.001
mDISCERN scores [median(IQR)]	2 (2-2)	3 (2-4)	2 (1-2)	<0.001

N,nubmer; IQR,interquartile range; GQS, Global Quality Score; mDISCERN, modified DISCERN.

TABLE 5 Correlation analysis between video quality score and video features.

	GQS		mDISCERN	
	r	p valve	r	p valve
GQS	–	–	0.340	<0.001
mDISCERN	0.340	<0.001	–	–
Likes	-0.125	0.088	-0.045	0.545
Comments	-0.068	0.358	-0.061	0.408
Collections	-0.035	0.632	-0.029	0.697
Video duration	0.177	0.015	0.017	0.821

GQS, Global Quality Score; mDISCERN, modified DISCERN.

audience, which contradicts previous research (33, 34) expectations. However, a positive correlation was observed between the duration of the video and its information quality, suggesting that high-quality lung cancer videos tend to offer detailed and comprehensive content rather than being short-lived or focused on generating quick traffic.

Our study has several limitations. Firstly, our evaluation of the quality of lung cancer video information is restricted to the Chinese platform, thus limiting its generalizability to other languages. Secondly, due to the time-sensitive nature of video content, we solely analyzed the quality of video information within a specific timeframe. In addition, we only evaluated the top 100 videos on both platforms, which may not be a comprehensive reflection of the video quality of the platforms. Lastly, our analysis is confined to the two most prominent video platforms in China, future studies should encompass additional platforms for a comprehensive analysis.

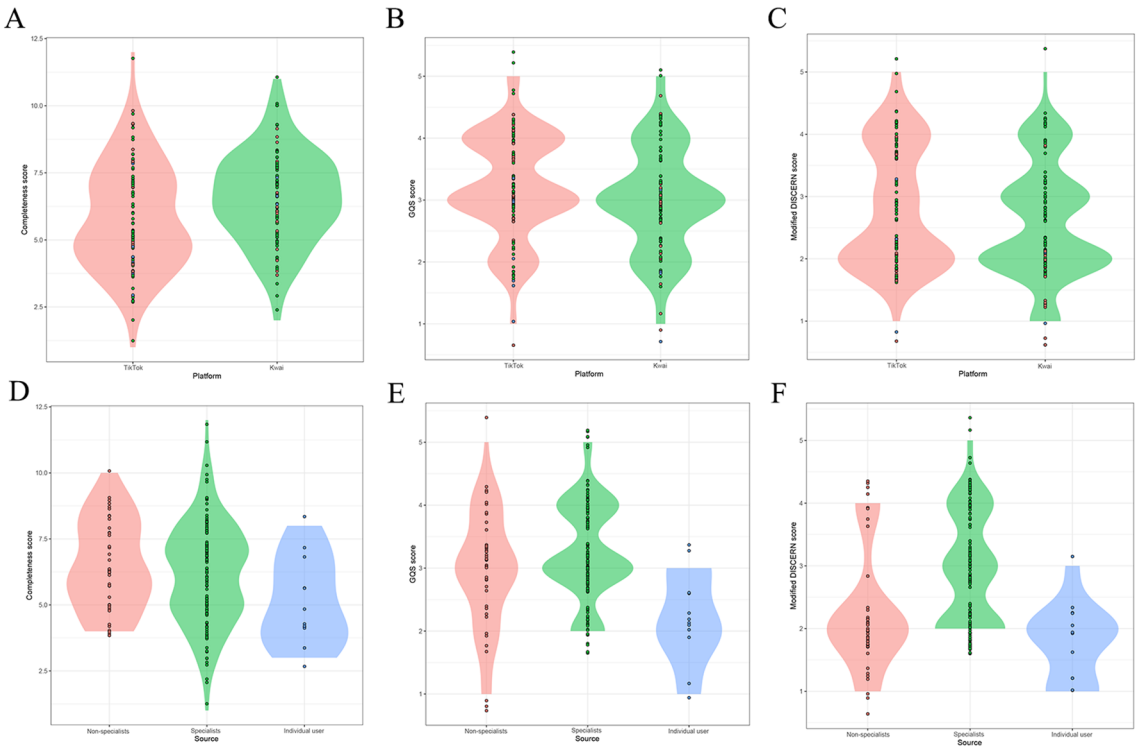

FIGURE 3
Comparison of video information quality from different sources. **(A–C)** Comparison of completeness score of different platforms, GQS scores and mDISCERN scores by violin plot. **(D–F)** Comparison of completeness score, GQS scores and mDISCERN scores by different users of violin plot.

Conclusion

A total of 186 lung cancer videos from both platforms were analyzed in this study. However, the video quality and reliability are suboptimal, and there is a dearth of reports on topics pertaining to lung cancer complications. Nevertheless, videos uploaded by experts elucidating lung cancer exhibited superior quality and comprehensiveness. In the future, it is imperative to further enhance the quality of short video information related to lung cancer and subject it to meticulous expert review for the development of more high-quality content. This will ensure accurate dissemination of knowledge about lung cancer to the platform audience and fortify its prevention and management.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding authors.

Ethics statement

Ethical approval was not required for the studies involving humans because the data of this study are publicly available and no ethical statement is required. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional requirements because The data of this study are publicly available and no ethical statement is required.

Author contributions

XZ: Writing – original draft, Writing – review & editing, Visualization. XY: Data curation, Formal analysis, Writing – review & editing. BS: Data curation, Investigation, Writing – review & editing. YZ: Writing – original draft, Writing – review & editing, Software, Supervision.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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The media literacy dilemma: can ChatGPT facilitate the discernment of online health misinformation?

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Online health misinformation carries serious social and public health implications. A growing prevalence of sophisticated online health misinformation employs advanced persuasive tactics, making misinformation discernment progressively more challenging. Enhancing media literacy is a key approach to improving the ability to discern misinformation. The objective of the current study was to examine the feasibility of using generative AI to dissect persuasive tactics as a media literacy scaffolding tool to facilitate online health misinformation discernment. In a mixed 3 (media literacy tool: control vs. National Library of Medicine [NLM] checklist vs. ChatGPT tool) × 2 (information type: true information vs. misinformation) × 2 (information evaluation difficulty: hard vs. easy) online experiment, we found that using dissecting persuasive strategies of ChatGPT can be equally effective when compared with the NLM checklist, and that information type was a significant moderator such that the ChatGPT tool was more effective in helping people identify true information than misinformation. However, the ChatGPT tool performed worse than control in terms of helping people discern misinformation. No difference was found in terms of perceived usefulness and future use intention of the ChatGPT tool and the NLM checklist. The results suggest that more interactive or conversational features might enhance usefulness of ChatGPT as a media literacy tool.

KEYWORDS

ChatGPT, information credibility, misinformation, media literacy, persuasive strategy

Introduction

Online health misinformation is defined as "health-related information disseminated on the Internet that is false, inaccurate, misleading, biased, or incomplete, which is contrary to the consensus of the scientific community based on the best available evidence" (Peng et al., 2023, p. 2133). Such misinformation is different from disinformation in that the creator of the information may not intentionally attempt to make it false or misleading. Online health misinformation carries serious social and public health implications (Romer and Jamieson, 2020; Roozenbeek et al., 2020). Previous studies have endeavored to incorporate techniques for identifying misinformation, including fact-checking labels (Zhang et al., 2021) and warning labels (Pennycook et al., 2020), and media literacy programs with a focus on identifying visual cues (e.g., layouts) or heuristic cues (e.g., sources) (Guess et al., 2020; Vraga et al., 2022). Although these strategies were found effective, a growing prevalence of sophisticated online health misinformation employs advanced persuasive tactics, such as enriching narrative elements, emphasizing uncertainty, evoking emotional responses, and drawing biased conclusions (Peng et al., 2023; Zhou et al., 2023). The next generation of media literacy

programs needs to help the audience fathom the persuasive tactics and critically analyze content and arguments.

Artificial intelligence (AI) and chatbots recently emerged as tools for automatic fact-checking (Guo et al., 2022) or assisting the analysis of arguments and persuasive tactics for misinformation discernment (Altay et al., 2022; Musi et al., 2023). This line of research is still in its nascence and needs more empirical support. Additionally, these tools may suffer from challenges in trust in conversational agents (Rheu et al., 2021) and psychological reactance (Reynolds-Tylus, 2019), rendering them ineffective; that is, people may have little trust in the analysis from AI, even if the analysis is accurate (Choudhury and Shamszare, 2023), and the advice from AI may make people feel irritated due to the threat to their freedom of independent thinking (Pizzi et al., 2021). These conflicting perspectives raise important questions about the feasibility of using ChatGPT as a media literacy tool. Therefore, the objective of the current study was to explore whether ChatGPT can effectively dissect persuasive strategies to support online health misinformation discernment, while also considering the potential limitations of this approach.

Misinformation and persuasive strategies

Infodemic, or the abundance of false or misleading information spreading rapidly through social media and other outlets, intensified during the COVID-19 pandemic and is becoming a global public health issue (Zarocostas, 2020). Various factors contribute to infodemic, including the contemporary media environments with echo chambers and social media filter bubbles (Flaxman et al., 2016); individual factors such as cognitive abilities and biases, political identity, and media literacy level (Nan et al., 2022); and information factors such as the persuasive strategies used to craft the misinformation (Peng et al., 2023). The current study attempts to examine how to improve health misinformation discernment through the angle of understanding persuasive strategies.

Twelve groups of persuasive strategies in online health misinformation were identified in a systematic review of published articles, including content analyses or discourse analyses of information factors that are prevalent in misinformation, and experiments that tested informational factors rendering people vulnerable to misinformation (Peng et al., 2023). These persuasive strategies include fabricating misinformation via vivid storytelling (Peng et al., 2023); using personal experience or anecdotes rather than scientific findings as evidence (Kearney et al., 2019); discrediting government or pharmaceutical companies (Prasad, 2022); making health issues political through the rhetoric of freedom and choice, us vs. them, or religious faith, moral values, or ideology (DeDominicis et al., 2020); highlighting unknown risk and uncertainty (Ghenai and Mejova, 2018); attacking science by exploiting its innate limitation (Peng et al., 2023); inappropriately using scientific evidence to support a false claim (Gallagher and Lawrence, 2020); exaggeration and selectively presentation or omission of information (Salvador Casara et al., 2019); making a conclusion based on biased reasoning (Kou et al., 2017); using fear or anger appeals in persuasion (Buts, 2020); using certain linguistic intensifiers to highlight the points (Ghenai and Mejova, 2018); and establishing the legitimacy of false claims by using certain cues to activate credibility heuristics of people (e.g., medical jargon, seemingly credible source) (Haupt et al., 2021).

Media literacy education to improve misinformation discernment

Combating misinformation consists of two primary lines of research. One is debunking misinformation via fact-check or correction (Chan et al., 2017; Walter et al., 2021). The other line of research is media literacy intervention to improve individuals' capabilities in searching, analyzing, and critically evaluating information (Hobbs, 2010). Media literacy education can help individuals effectively search for information and discover credible sources, interpret and evaluate the information through a critical lens, and be aware of one's biases. A recent meta-analysis demonstrated that media literacy intervention is an effective tool to improve misinformation discernment (Lu et al., 2024). This meta-analysis also revealed that intervention time (ranged from a few minutes to 8 weeks) was not a moderator for the effect size of the outcomes of credibility assessment or attitude related to misinformation, meaning that shorter duration interventions (Guess et al., 2020; Qian et al., 2023) had a similar effect size as long-term interventions (Mingoia et al., 2019; Zhang et al., 2022). Therefore, short and focused interventions with variability to address the fast-paced media environment are advocated (Lu et al., 2024).

Technology-enhanced media literacy tools

What is noticeable is that the meta-analysis demonstrated a moderating effect of the delivery form of the media literacy intervention (Lu et al., 2024). Among the four different forms–course, video, graphic, and game, the *post-hoc* analysis revealed that game-based media literacy interventions (Basol et al., 2021; Roozenbeek and van der Linden, 2019) generally have a larger effect size in terms of assessment of misinformation. This larger effect size can be explained by engaging participants to learn the manipulativeness or persuasive strategies in misinformation via actively playing a role of misinformation creator. For instance, in the *Bad News* game (Roozenbeek and van der Linden, 2019), the participant's goal was to produce news articles using persuasive strategies, such as making a topic look either small and insignificant or large and problematic, or communicating the conspiracy theories to the audience to distrust mainstream narrative. Similarly, in the *Go Viral* game (Basol et al., 2021), the participant's goal was to create emotionally evocative social media posts, or use fake experts to back up the claim, all of which are manipulations through persuasive strategies. This prior evidence of the success of game-based media literacy intervention demonstrated that learning about persuasive strategies can be effective in improving misinformation discernment.

Another type of tools to teach about persuasive strategies may be AI-based tools to prompt the audience to be aware of the persuasive strategies used in the encountered information. AI-based fact-checking or *post-hoc* correction tools have been used extensively in the first line of reach to combat misinformation (Guo et al., 2022). More recently, chatbots emerged as a media literacy tool to assist the analysis of arguments for misinformation discernment (Altay et al., 2022; Musi et al., 2023; Zhao et al., 2023). For instance, the chatbot delivering valid counter-argument was able to move people into a more positive attitude toward GMOs (Altay et al., 2022). The *Fake New Immunity Chatbot* (Musi et al., 2023) interactively taught people to recognize valid arguments and fallacies through reason-checking. Specifically,

the *Fake New Immunity Chatbot* scaffolds the investigation of the connections of the claims and their evidential context by nudging the users into asking critical questions and identifying fallacies such as cherry-picking and false analogy.

These early studies of chatbot-based approaches for combating misinformation have demonstrated feasibility. However, empirical evidence of their effectiveness is lacking. Prior media literacy studies demonstrated that the game-based interventions were particularly successful due to their ability to interactively teach persuasive strategies. The early studies of the chatbot-based approach also alluded that revealing biased reasoning, one of the persuasive strategies commonly used in misinformation, was a promising media literacy approach to combat misinformation, as operationalized as people's attitude toward misinformation or credibility assessment of misinformation. ChatGPT, one of the most widely used large language model (LLM)-based chatbots, has the potential to iteratively reveal persuasive strategies in the information people encounter. Flagging the persuasive strategies employed in the information to the users also serves as an interactive media literacy approach, i.e., teaching users how persuasive strategies are used and increasing their critical thinking. Currently, no empirical study is available to examine the potential of using ChatGPT as a media literacy tool to dissect persuasive strategies (termed as ChatGPT tool thereafter). Therefore, the present study attempts to fill this gap by adding empirical evidence for feasibility. The benchmark to be compared to is a simple media literacy checklist provided by the National Library of Medicine (NLM) as well as a control group. We propose:

> RQ1: How will the ChatGPT tool compare to (a) the NLM media literacy checklist or (b) the control group for users' accuracy in information credibility assessment?

The ChatGPT tool may be effective, but skepticism about AI-powered technology, especially in the field of misinformation detection or correction, is one challenge. The skepticism is rooted in multiple factors, including fears of AI, especially the bias in AI algorithms (De Vito et al., 2017; Zhan et al., 2023), and a lack of understanding about how these systems operate (O'Shaughnessy et al., 2023). Moreover, incidents where AI has amplified misinformation (Zhou et al., 2023) can further erode confidence. Additionally, although flagging persuasive strategies may teach media literacy, people may not like the fact that they are being told by AI what to think and psychological reactance may arise (Pizzi et al., 2021). Therefore, we explore the following research questions to examine whether people accept the ChatGPT tool for assisting information evaluation.

> RQ2: Will participants rate the ChatGPT tool more useful than the NLM checklist for information evaluation?
>
> RQ3: Will participants be more likely to use the ChatGPT tool than the NLM checklist for future information evaluation?

Method

Study design and procedure

A 3 (media literacy tool: control vs. NLM checklist vs. ChatGPT tool) × 2 (information type: true information vs. misinformation) × 2 (information evaluation difficulty: hard vs. easy) online experiment was employed on *Qualtrics* for randomization. The main independent variable for hypothesis testing was the media literacy tool, a between-subjects variable. The other two independent variables were within subjects. Both true and misinformation were included to control for false positives—the tendency of false skepticism of all information, including true information. Information evaluation difficulty was included to explore whether the media literacy tool works for both simple-to-detect misinformation and well-crafted misinformation.

After giving consent, participants' general information literacy was assessed. Then, they were randomly assigned to one of the three media literacy tool conditions. Except in the control, participants were introduced to how those media literacy tools work and examined their comprehension of these tools, and the correct answers were provided to the participants to reinforce their understanding. Then, all participants viewed four pieces of randomly displayed information (two pieces of true information and two pieces of misinformation) identified from our pilot study. After reading each piece, they were asked about message credibility and issue importance. Participants in the ChatGPT tool and NLM checklist conditions also answered questions about perceived usefulness and future use intention. Participants in the ChatGPT condition were also evaluated on their comprehension of ChatGPT dissecting persuasive strategies, ChatGPT's dissecting of the persuasive strategies, and ChatGPT's dissecting of persuasive strategies.

Participants

A total of 153 participants completed the online experiment. After removing one who failed two of the four attention check tests, 12 who failed the comprehension check of dissecting persuasive strategies of ChatGPT, and one who failed both, 139 were included in the analysis. In total, 52 were in the control condition, 56 in the NLM checklist condition, and 31 in the ChatGPT tool condition. There were fewer participants in the ChatGPT condition due to the removal of participants failing the comprehension and attention check. Among them, 42% ($n = 58$) identified as male, 56% ($n = 78$) as female, 4% ($n = 3$) did not disclose gender; 73% ($n = 101$) identified as White, 15% ($n = 21$) as Black or African American, 7% ($n = 10$) as Asian, 2% ($n = 3$) as mixed race, and 3% ($n = 4$) did not disclose ethnicity or identified as other ethnicity; 81% ($n = 113$) had at least some college education, 15% ($n = 21$) were high school graduates, 1% ($n = 2$) did not graduate from high school, and 2% ($n = 3$) did not disclose education.

Stimuli

Providing a checklist is a commonly used short-term media literacy intervention tool and has been found to be effective (Ghenai and Mejova, 2018). One comparison condition was the NLM checklist.[1] The NLM checklist was introduced before the participants started to read and evaluate the information. To ensure the accessibility of the checklist, a screenshot was provided to participants. Then, before

1 https://medlineplus.gov/webeval/webevalchecklist.html

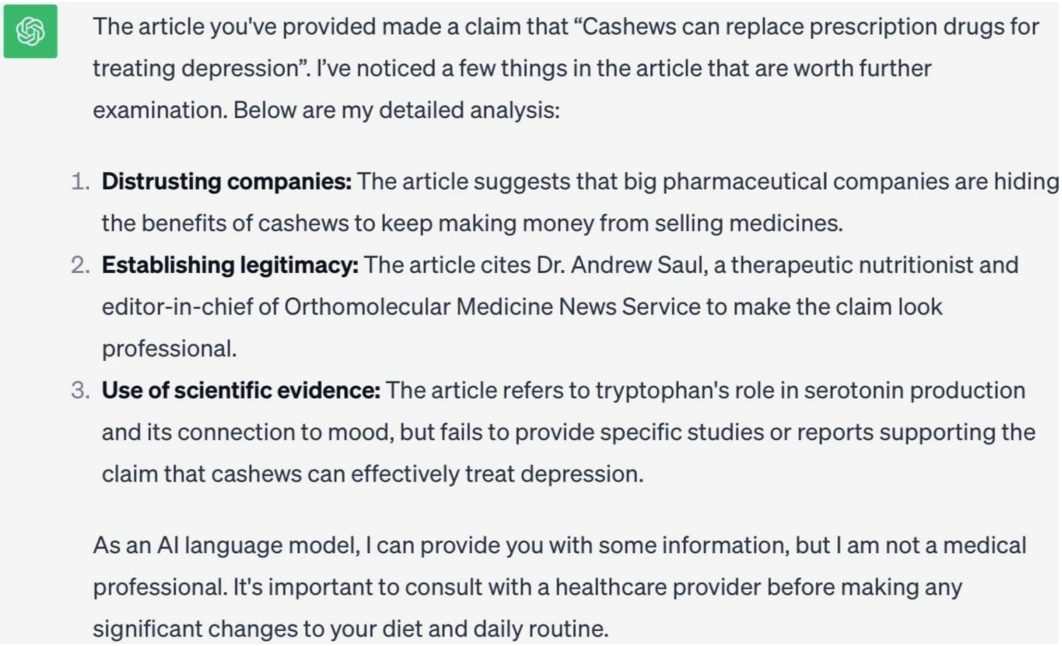

FIGURE 1
Screenshot of using ChatGPT to dissect persuasive strategies in misinformation.

they read each of the four pieces of information, they were prompted to refer to the NLM checklist to assist in information evaluation.

The ChatGPT tool condition was manipulated by showing the participants ostensible screenshots of analysis of persuasive strategies in the information encountered (Figure 1). Participants were explained that ChatGPT is an AI tool that can be trained to dissect persuasive strategies to increase people's critical thinking for information evaluation. The response of ChatGPT of explaining the persuasive strategies in each piece of information was displayed right after they were exposed to the information. The control group was not provided with any media literacy tool.

In the pilot study, 79 participants were recruited from CloudResearch to complete the evaluation of six pieces of randomly displayed health-related information (Table 1). The articles were written with 9[2] of the 12 persuasive strategies embedded. Each article was sent into ChatGPT 3.5 and ChatGPT 3.5 was then asked to identify persuasive strategies in it. The authors modified the responses by ChatGPT 3.5 by removing errors and creating the stimuli of the ChatGPT condition.

By nature, some information is more difficult for people to accurately assess veracity, partly due to the novelty of the information. Two pieces of information were not selected in the main study because it was either too easy or too difficult to discern veracity. Four pieces were chosen for the main study, and they differed in terms of information evaluation difficulty as demonstrated by accuracy rate. Therefore, information evaluation difficulty was included as an independent variable in the main study.

Measures

Accuracy in information credibility evaluation

Participants rated the information credibility of each piece by indicating their agreement using a 5-point scale to rate the piped claim of the article as "believable," "authentic," and "accurate" (Appelman et al., 2016). Because participants read both true and misinformation, simply comparing the perceived message credibility would not capture accuracy in information credibility assessment. Therefore, we calculated the distance to ground truth, i.e., 5 being the ground truth for true information and 1 being the ground truth for misinformation. The greater the distance to ground truth, the less accuracy in information credibility evaluation.

Perceived usefulness of media literacy tool

Four items adapted from Taylor and Todd's (1995) scale were used to assess the perceived usefulness of the NLM checklist and the ChatGPT tool. Example items were as follows: "I think [piped tool] is useful for information evaluation" and "Overall, using [piped tool] for information evaluation will be advantageous."

Behavioral intention of future use

Three items were adapted from Davis' (1989) scale to assess future use intention. An example item was as follows: "Using

2 Nine of the 12 strategies were features in the articles: fabricating misinformation via vivid storytelling; using personal experience or anecdotes rather than scientific findings as evidence; discrediting government or pharmaceutical companies; attacking science by exploiting its innate limitation; inappropriately using scientific evidence to support a false claim; making a conclusion based on biased reasoning; using fear or anger appeals in persuasion; using certain linguistic intensifiers to highlight the points; and establishing the legitimacy of false claims by using certain cues to activate people's credibility heuristics (e.g., medical jargon, seemingly credible source).

TABLE 1 Six pieces of information in the pilot study.

	Accuracy rate (%)	Main study
Misinformation		
Cashews can replace prescription drugs for treating depression	44	Yes
Preservatives in sunscreen cause breast cancer	39	No
Imported pet food might be contaminated with radioactive substances	60	Yes
True information		
Potential link between caffeine and reduced risk of Alzheimer's	73	Yes
Ginger can improve digestive health and relieve menstrual cramps	94	No
Lone star tick bite can make people allergic to red meat	50	Yes

[piped tool] for information evaluation is something I would do in the future."

All the above measures were rated on a 5-point Likert scale. Additionally, issue importance (Paek et al., 2012) and general information literacy (van der Vaart and Drossaert, 2017) were included as control variables.

Data analysis

To answer R1a, we conducted a mixed-model analysis of covariance (ANCOVA) to compare the effectiveness of the ChatGPT tool with the control, with information type (true information vs. misinformation) and information evaluation difficulty (hard vs. easy) as within-subjects factors, controlling for issue importance. A similar mixed-model ANCOVA was used to compare the ChatGPT tool with the benchmark of the NLM checklist, to answer RQ1b.[3] For RQ2 and RQ3, we did one-factor ANCOVA, controlling for information literacy to compare the ChatGPT tool with the NLM checklist in terms of perceived usefulness and future use intention of media literacy tools.

3 We also did a 3 × 2 × 2 ANCOVA and the results were comparable: there was a main effect of information type $F(1,542)=8.35$, $p=0.004$. An interaction effect was found between media literacy tools and information type $F(1,542)=8.02$, $p<0.001$. Issue importance was a significant covariate, $F(1,542)=5.11$, $p=0.024$. Similarly, a 2 × 2 × 2 ANCOVA was conducted to compare the NLM checklist with the control group. No main effects or two-way interactions were found. A marginally significant three-way interaction was found, $F(1,422)=3.89$, $p=0.049$.

Results

ChatGPT tool vs. control

To compare the ChatGPT tool with the control group (RQ1a), the ANCOVA results indicated a significant main effect of information type, $F(1,322)=7.03$, $p=0.008$, suggesting better accuracy in credibility evaluation in true information than misinformation. Additionally, a significant interaction effect emerged between media literacy tools and information type, $F(1,322)=17.16$, $p<0.001$. There was also a marginally significant interaction effect between information type and information evaluation difficulty, $F(1,322)=3.93$, $p=0.048$. No other effects were found significant. A subsequent *post-hoc* analysis focused on the interaction between media literacy tools and information type given its robustness. The *post-hoc* pairwise comparison with Tukey's adjustment revealed worse accuracy in information credibility evaluation in the ChatGPT tool condition only for misinformation, exhibiting a greater distance to ground truth ($M=2.18$, $SE=0.12$) than the control condition ($M=1.68$, $SE=0.10$), $p<0.001$. Moreover, within the ChatGPT tool condition, accuracy in information credibility evaluation was markedly worse for misinformation ($M=2.18$, $SE=0.12$) than for true information ($M=1.44$, $SE=0.12$), $p<0.001$, demonstrated by a greater distance to ground truth.

ChatGPT tool vs. NLM checklist

To answer RQ1b, the ANCOVA test revealed a significant main effect for information type, $F(1,338)=16.45$, $p<0.001$. Issue importance was also found to be a significant covariate, $F(1,338)=8.70$, $p=0.003$. An interaction effect was found between media literacy tools and information type, $F(1,338)=6.66$, $p=0.01$. No other effects were significant. The *post-hoc* pairwise comparison with Tukey's adjustment indicated that the ChatGPT tool resulted in less accuracy in information credibility evaluation of misinformation ($M=2.19$, $SE=0.13$) than true information ($M=1.43$, $SE=0.13$), $p<0.001$, demonstrated by a greater distance to ground truth. However, no discernible differences were noted in the direct comparison between the NLM checklist and ChatGPT tool across both true ($p=0.419$) and false misinformation ($p=0.132$).

To answer RQ2, the one-factor ANCOVA demonstrated that there were no differences in the perceived usefulness of the ChatGPT tool ($M=3.85$, $SD=0.68$) and the NLM checklist ($M=4.08$, $SD=0.81$), $F(1,84)=1.85$, $p=0.177$. No statistically significant differences in future use intentions were found between the ChatGPT tool ($M=3.19$, $SD=1.08$) and the NLM checklist ($M=3.65$, $SD=1.04$), $F(1,84)=3.91$, $p=0.051$, answering RQ3. Note that general information literacy was a significant covariate, meaning that general information literacy was positively associated with the perception of the usefulness of media literacy tools, $F(1,84)=7.71$, $p=0.007$, as well as people's intention to use media literacy tools in the future, $F(1,84)=4.83$, $p=0.031$.

Discussion

Using dissecting persuasive strategies of ChatGPT can be equally effective when compared with the NLM checklist, and that

information type was a significant moderator such that ChatGPT was more effective in helping people identify true information than misinformation. However, using ChatGPT was worse than the control when it comes to misinformation discernment. The ChatGPT tool was not evaluated to be different from the NLM checklist in terms of usefulness and future use intention.

Despite that existing literature has documented that using chatbot-based approaches for combating misinformation could be feasible (Altay et al., 2022; Musi et al., 2023; Chan et al., 2017), our finding suggests that reading the rationale from ChatGPT for information veracity evaluation actually resulted in worse misinformation discernment compared to control. The findings of our study provided insights about several important factors to consider when it comes to testing the effectiveness of using chatbots as a media literacy tool. The first factor, which is also an important contribution of our current study, is the extent to which the studies mirror the complex information environment by mixing different information types (i.e., true and misinformation) and difficult levels (i.e., easy and hard) when asking participants to discern information credibility. Recent studies, such as the *Fake New Immunity Chatbot* (Musi et al., 2023), have reported the effectiveness of using chatbots to teach participants to recognize fallacies through reason-checking, but those studies were conducted in a context where participants learned persuasive strategies by analyzing misinformation only. In our study, both true and misinformation were presented to participants, which may have created more challenging tasks about information discernment. Our finding implies that future research testing media literacy tools for information discernment should include both misinformation and true information to better demonstrate the effectiveness of the tool in the complex information environment.

The second factor that may affect the effectiveness of a chatbot tool is related to interactivity and participants' engagement in learning. Previous literature has demonstrated that the game-based interventions were particularly successful due to their ability to interactively teach persuasive strategies (Buts, 2020). Our study involved participants' reading of pre-generated analysis of persuasive strategies from ChatGPT. The reading of texts is at a different level of interactivity and user engagement enabled by game-based interventions. Even though we have ensured that participants read and comprehended the analysis of persuasive strategies, it is possible that participants could not cognitively internalize the knowledge and skill points to connect persuasive strategies to the quality of information. For more complicated cognitive skills, such as learning persuasive strategies, it may be critical to create an enactive experience scaffolded by interactive steps. To better test the effectiveness of AI tools facilitating information discernment by dissecting persuasive strategies, future research should allow the participants to use the tools directly to gauge effectiveness.

Moreover, our findings showed that information literacy was positively associated with the perception of the usefulness of media literacy tools and their intention to use the media literacy tools in the future, although the perceived usefulness and use intention did not differ between the ChatGPT tool and the NLM checklist. This is consistent with the existing literature that has stressed the important role of information literacy in facilitating the identification of fake news (Jones-Jang et al., 2021). Our study reveals that people with higher levels of information literacy also appreciate media literacy tools more and are more likely to use them. This implies that such media literacy tools might benefit individuals who already have somewhat sufficient information literacy. In other words, those who have low information literacy and mostly need assistance in information discernment may not take advantage of such tools, possibly resulting in "rich get richer." Future research may also explore how to encourage individuals with low information literacy to accept technological tools to facilitate their information discernment process.

The ChatGPT tool did not differ from the NLM checklist in terms of accuracy in information credibility assessment for both true and misinformation nor did it differ from the control for true information assessment. However, the ChatGPT tool was found to be more effective in helping people discern true information than misinformation. This was a promising finding because one of the concerns was that highlighting persuasive strategies in true information might heighten people's perception of persuasive intent, which may increase suspicion even for true information, resulting in distrust of credible information (Krause et al., 2022). The fact that the ChatGPT tool did not result in false positives—mistakenly identifying true information as false—was encouraging. In fact, extensive research findings on identifying misinformation do not easily translate into how people evaluate true information (Krause et al., 2022). Uncertainties and other sociopolitical factors associated with true information may make people dismiss it. The ChatGPT tool seems to have the potential to enhance people's confidence in verifying true information by providing reasoning.

An intriguing finding was that the ChatGPT tool performed worse than the control when it comes to misinformation. The lower effectiveness of the ChatGPT tool may be due to people's lack of trust in ChatGPT and psychological reactions triggered by viewing information analysis of ChatGPT. For example, people may have ethical concerns such as moral obligations and duties of AI and its creators (Siau et al., 2020). Biased or inappropriate content may still appear due to limitations related to the algorithms and training data (Zhou et al., 2023). People may feel their freedom and autonomy in assessing information be threatened when ChatGPT actively offers advice (Pizzi et al., 2021). Future research should examine the mediation mechanism, including but not limited to trust in ChatGPT and psychological reactions, to explain this unexpected effect.

Limitations

There are several limitations in our study. The first limitation is related to the combination of skill learning and outcome testing into one process. Future research may first establish the learning outcome; that is, people truly understand and acknowledge the usefulness of using persuasive strategies to identify misinformation and then presenting people with a different set of information to apply the knowledge and skills learned for information discernment. In this way, we could be more confident in disentangling the effects of using persuasive strategies as an approach to improve media literacy and using ChatGPT as a tool for dissecting persuasive strategies for people while they are processing information.

In addition, the ChatGPT condition had a lower number of participants, due to a larger number of participants failing the comprehension check. The fact that they failed the comprehension check showed that they did not understand the persuasive strategies dissected by the ChatGPT tool. This further demonstrated that it is important to first establish that participants understand the persuasive strategies more in-depth before they use the ChatGPT tool to dissect

the persuasive strategies just in time. Future research could investigate how to better present persuasive strategies to the users. For example, future research may inform participants about the ground truth in the first step of learning persuasive strategies so that they could establish the connection between the persuasive strategies and the veracity of information (i.e., the learning process) and then apply the knowledge and skills to information discernment tasks (i.e., the outcome testing). Finally, the ChatGPT condition in terms of its responses regarding the veracity of the articles was created by removing errors in the actual responses of ChatGPT of identifying the persuasive strategies. In other words, the findings were based on the assumption that ChatGPT was able to accurately identify persuasive strategies. Given that performance of ChatGPT has limitations, future research may explore how people's trust in capabilities of ChatGPT may have played a role in their reliance on the media literacy information provided by ChatGPT.

Conclusion

The current study examined the effectiveness of using dissecting persuasive strategies of ChatGPT as a media literacy tool to assist people's evaluation of online health information. Information type was a significant moderator such that ChatGPT was more effective in helping people identify true information than misinformation. This finding suggests that dissecting persuasive strategies of ChatGPT is promising to enhance people's confidence in verifying true information by providing reasoning, which has important implications for proper evaluations of true information given the complex information environment wherein true claims are not always clear-cut. In addition, while using dissecting persuasive strategies of ChatGPT can be equally effective when compared with the NLM checklist, the ChatGPT tool performed worse than control in terms of helping people discern misinformation. These findings suggest an alternative delivery of a media literacy program may be needed, such as using conversational features of ChatGPT so that people can interact and engage more in the learning of persuasive strategies.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Institutional Review Board at Michigan State University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants indicated their informed consent before the start of the study.

Author contributions

WP: Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing. JM: Conceptualization, Funding acquisition, Methodology, Writing – original draft, Writing – review & editing. T-WL: Formal analysis, Investigation, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Profiling antivaccination channels in Telegram: early efforts in detecting misinformation

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Introduction: Telegram's privacy-focused architecture has made it a fertile ground for the spread of misinformation, yet its closed nature poses challenges for researchers. This study addresses the methodological gap in capturing and analysing misinformation on Telegram, with a particular focus on the anti-vaccination community.

Methods: The research was conducted in three phases: (1) a structured review of literature on misinformation dissemination via Telegram, (2) development of a conceptual framework incorporating features of message creators, message content, intended targets and broader social context, and (3) application of this framework to anti-vaccination Telegram channels using latent profile analysis (LPA). A dataset comprising 7,550 messages from 151 Telegram channels was manually annotated and analysed.

Results: LPA identified distinct profiles among the channels. Malicious and non-malicious channels showed significant differences in their communication patterns, particularly in the use of crisis framing, discursive manipulation, and thematic orientation. T-tests confirmed these distinctions.

Discussion: The findings highlight Telegram's unique dynamics in misinformation spread and support the utility of the proposed framework in isolating harmful content. The study underscores the need for tailored analytical strategies for platforms with non-standard affordances and suggests that content-based profiling may assist in proactive moderation.

KEYWORDS

malicious channels, misinformation, antivaccination movement, telegram platform, latent profile analysis (LAT)

1 Introduction

Telegram is a cloud-based, cross-platform instant messaging service with over 700 million monthly active users globally (Ng et al., 2024). Beyond personal messaging, Telegram is used for news dissemination, political communication and organizing social movements, making it a fertile ground for misinformation (Sosa and Sharoff, 2022). Telegram is distinguished from other online social networks by its enhanced encryption and privacy features which appeal to users prioritizing privacy and security in their communications (Terracciano, 2023). It is known as a crucial outlet for extremist groups and the spread of politically motivated misinformation (Ruffo et al., 2022; Willaert et al., 2022). However, enhanced encryption can be an obstacle both for collecting high-quality data (Liz-López et al., 2024; Ng et al., 2024) and for detecting misinformation (Ng and Taeihagh, 2021). Despite the potential for misinformation to spread, Telegram remains under-researched in the realm of misinformation

(Urman et al., 2021; Bodrunova and Nepiyuschikh, 2022) with limited evidence that the insights from misinformation research on other platforms could apply to Telegram.

Hence, the research presented here addresses two critical questions: *What are the* methodological *challenges in collecting high-quality misinformation data on Telegram and how can a tailored conceptual analysis framework for identifying malicious channels be developed and validated?* This study aims to explore these challenges and take initial steps toward developing and testing a conceptual framework that accounts for Telegram's unique features and the nature of spreading misinformation. To answer these research questions, this study was structured into three main phases (see Figure 1).

First, a structured literature review was conducted to understand the work that has already been conducted on misinformation in Telegram. Second, we built a conceptual framework focusing on four major components: features of creators/spreaders, message content, target victims and social context. This framework was designed specifically for Telegram to address the unique challenges posed by Telegram's structure and functionality due to its encryption, private and public channel structures, and lack of content moderation, which influence how misinformation spreads. Unlike traditional social media platforms, Telegram's design allows for rapid, unchecked dissemination within closed groups and large audiences alike, requiring an approach that accounts for these unique dynamics. Third, we tested the conceptual framework by examining its utility within the context of the antivaccination community on Telegram. Data was collected from 151 anti-vaccination Telegram channels, resulting in a dataset of 7,550 messages. These messages were manually annotated according to the conceptual framework. Lastly, we employed latent profile analysis to profile misinformation channels. Profiling channels based on their track record of misinformation requires careful methodology and thorough fact-checking, and enough data is needed from each channel to make a reasonable assessment: channel metadata, textual data, social media posts, and contextual data. If done transparently, profiling channels for misinformation can be a useful tool to help audiences gauge reliability, and it can also assist platforms or researchers in understanding where and how misinformation spreads (Shen and Wu, 2024).

By focusing on the antivaccination movement, this research aims to provide valuable insights into the dynamics of malicious channels on Telegram. The World Health Organization (2019) has listed the antivaccination movement as one of the top 10 global health threats. Despite conclusive evidence that the benefits of vaccination far outweigh the risks, antivaccination misinformation continues to thrive, particularly on social media platforms where it can easily reach a broad audience (Schlette et al., 2022; Ortiz-Sánchez et al., 2020; Bode and Vraga, 2018; Chua and Banerjee, 2018). Movements against vaccination have become increasingly active online, using the COVID-19 crisis to broaden their influence (Bonnevie et al., 2021). A key strategy involves amplifying and dramatizing reports of adverse reactions to vaccines in media and public discourse (Ball, 2020; Germani and Biller-Andorno, 2021). Telegram, in particular, has emerged as a widely used platform for disseminating extreme viewpoints (Rogers, 2020). It markets itself as a fast and secure messaging service, offering strong encryption and anonymity while also enabling users to reach large audiences without content moderation or restrictions (Urman et al., 2021). Understanding malicious channels behind the antivaccination movements is crucial for developing effective strategies to combat misinformation and protect public health. Hence, this study not only addresses a significant gap in existing literature but also contributes to the broader efforts of safeguarding information integrity in the digital age.

2 Related work

To establish our study within the existing scholarly discourse, we systematically reviewed research on misinformation within Telegram, drawing from major academic databases. This review aimed to examine data collection methods, analytical approaches, available datasets, and methodological gaps in detecting misinformation on the platform. Table 1 and the subsequent section outline the systematic literature review strategy we employed.

In the Scopus database, a search query combining terms related to misinformation and data collection on Telegram yielded 29 initial articles, while the Web of Science database identified 12 articles. The initial search results were then screened by reviewing the titles, abstracts and keywords of the articles. The screening process involved evaluating the relevance of each article based on specific inclusion criteria (1) only articles published in English were included to

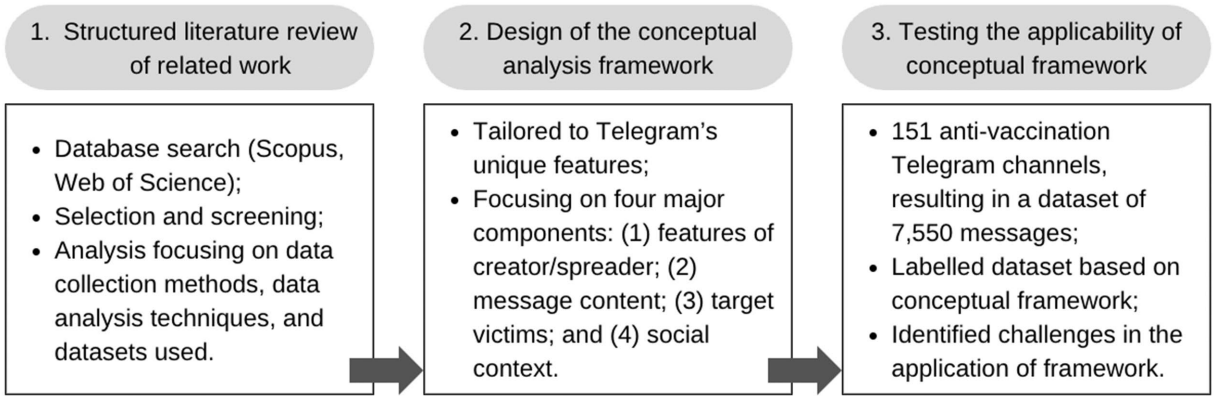

FIGURE 1
Key phases of research (source: Authors, 2024).

TABLE 1 Database search string (source: Authors, 2024).

Database	Query string/keywords	Initial	Final
Scopus	TITLE-ABS-KEY (misinformation OR disinformation OR fake news OR rumors OR rumors OR misleading) AND TITLE-ABS-KEY (dataset OR data set OR data collection OR database OR corpora) AND TITLE-ABS-KEY (telegram)	29 entries	15 entries
Web of science	TOPIC = (fake news OR misinformation OR disinformation OR rumors OR rumors OR misleading) AND (dataset OR data set OR data collection OR database OR corpora) AND (Telegram)	12 entries	

maintain accessibility; (2) studies had to involve Telegram as a primary platform for data collection or analysis; (3) peer-reviewed journal articles and conference papers were included; and (4) provide sufficient methodological detail regarding data collection, dataset creation or analytical techniques used to study misinformation on Telegram. No specific starting date was selected since research on Telegram is relatively recent. Following the screening process, 15 articles from both databases were included in the final analysis.

The literature on misinformation in Telegram research highlights several key challenges: the lack of standardized data collection methods, the fragmentation of analytical approaches, the limitations in generalizability due to linguistic and cultural constraints, and ethical concerns related to user privacy. Additionally, the evolving nature of misinformation and the platform's structural characteristics make it difficult to track and analyze false narratives. While studies employ diverse methodological techniques, their lack of integration restricts the formation of overarching conclusions. The review also identifies the need for validation and replication studies to enhance research reliability and calls for the development of cross-lingual, adaptable datasets.

A major obstacle in Telegram misinformation research is the inconsistency in data collection methods, which leads to variations in dataset quality and scope. Some researchers, such as Vanetik et al. (2023), have used web scraping and crawling techniques to compile large-scale datasets, capturing user interactions and content dissemination patterns. Others, including Claudino de Sá et al. (2023) and Ng et al. (2024), have implemented real-time monitoring systems, such as MST and BATMAN, to track misinformation as it spreads during major events. While these approaches offer valuable insights, the absence of standardized procedures makes it difficult to compare findings across studies or establish broader patterns.

The lack of methodological integration is another significant limitation. Research on Telegram misinformation employs a wide range of analytical techniques, including content analysis, sentiment analysis, natural language processing (NLP), and machine learning models. Studies such as those by Bodrunova and Nepiyuschikh (2022) and Ei and Kiat (2023) apply content and sentiment analysis to assess emotional tone and dominant narratives. Others, including Jahanbakhsh-Nagadeh et al. (2021a) and Yang et al. (2023), leverage NLP and machine learning to classify misinformation and evaluate chatbot performance. Additionally, researchers like Terracciano (2023) and Willaert et al. (2022) have introduced alternative frameworks, such as semiotics and visual network analysis, to examine misinformation dynamics. While these varied approaches provide different perspectives, their lack of integration prevents the formulation of universal conclusions.

Another challenge concerns the generalizability of findings. Most studies focus on specific linguistic or cultural contexts, limiting their applicability to broader misinformation trends. Comparative corpus analysis, such as that conducted by Maschmeyer et al. (2023) and Boumechaal and Sharoff (2024), attempts to bridge this gap by examining Telegram's anti-vaccine discourse alongside general COVID and English-language corpora. However, research remains largely fragmented, raising concerns about whether findings from one context can be applied elsewhere.

Ethical and privacy concerns add further complexity to Telegram misinformation research. The platform's encryption and privacy settings restrict access to high-quality data (Ng et al., 2024), making misinformation detection more difficult (Ng and Taeihagh, 2021). Unlike many other social media platforms, Telegram lacks content moderation, allowing misinformation to spread unchecked within echo chambers (Bodrunova and Nepiyuschikh, 2022). Additionally, forwarding mechanisms create cascading effects that amplify false narratives (Terracciano, 2023), yet the private nature of many channels makes it difficult to map misinformation flows comprehensively.

Finally, the dynamic nature of misinformation on Telegram poses ongoing challenges. Similar to other platforms, Telegram experiences constant shifts in deceptive tactics, requiring researchers to continuously adapt their methods (Ahmad et al., 2019; Aïmeur et al., 2023; Mathiesen, 2019; Panda and Levitan, 2021; Moran et al., 2023). The platform's multilingual environment further complicates misinformation detection, necessitating cross-lingual datasets and more adaptable analytical techniques. Given the relatively recent surge in Telegram misinformation research, validation and replication studies remain essential to improving reliability and ensuring methodological rigor.

Addressing these challenges requires the refinement of data collection strategies and the development of standardized, cross-lingual datasets. The growing body of research highlights the need for methodological coherence, better integration of analytical techniques, and enhanced ethical considerations to effectively study and combat misinformation on Telegram.

3 Conceptual framework for data collection

The structured literature review presented in Section 2 highlights a scarcity of conceptual frameworks explicitly designed for analyzing misinformation on Telegram. However, numerous research approaches have been documented for other social networking platforms, including Facebook (Schmidt et al., 2018), X/Twitter (Castillo et al., 2011; Horawalavithana et al., 2023) and other social media networks (Yang et al., 2012). Non-platform-specific frameworks also offer distinct perspectives for analyzing disinformation online (François, 2019; Pamment, 2020; Wardle and Derakhshan, 2017; Bontcheva et al., 2020). After thoroughly reviewing these methodologies, we have adapted Zhang and Ghorbani's (2020) approach, focusing on four

major components: (1) features of creator/spreader; (2) message content (focus on specific topics); (3) target victims (audience); and (4) social context. This multi-dimensional approach, tailored to analyze the features of datasets on Telegram, helps avoid too narrow a focus and prevents a one-dimensional interpretation of complex disinformation phenomena. By systematically categorizing and analyzing these facets of online misinformation, we aim to facilitate a deeper understanding of its spread and impact on Telegram.

3.1 Features of creators/spreaders

As part of our conceptual analysis framework, malicious channels can be defined as entities where fake news is created, published and spread (Zhou and Zafarani, 2020). They intentionally spread deceptive information to enhance their social influence, often driven by personal or financial gain (Shu et al., 2020). In examining actors on online social networks, literature frequently highlights three critical features: (1) *Creators vs. spreaders*. Creators generate and trigger the spread of disinformation, while spreaders amplify its reach. Understanding the actors behind anti-vaccine messages is crucial, as the virality of misinformation depends on these users (Karami et al., 2021). The literature consistently points out that creators are often highly motivated and capable of producing disinformation for personal or financial gain (Patel and Constantiou, 2020); (2) *Bots vs. humans*. Bots are defined as pieces of software programmed to pursue specific tasks, which can present simple and sophisticated behavior into the network, creating, sharing, and rating content and interacting with other users and bots (Moguel-Sánchez et al., 2023). In this analysis, bots were detected as they sent messages in bulk and created messages repeatedly. Both bots and humans significantly contribute to misinformation spread. Bots, or automated accounts, exploit online ecosystems to disseminate false content. Despite this, research shows that humans are still major propagators of misinformation (Schlette et al., 2022; Rogers, 2020; Vosoughi et al., 2018). Identifying bots is essential, but humans' inability to distinguish them from real accounts leads to the inadvertent spreading of misinformation (Torabi Asr and Taboada, 2019). The literature emphasizes that while bots increase the volume of misinformation, humans are crucial to its spread (Wang et al., 2019); and (3) *Individual vs. Group actors*. Misinformation is propagated by both individuals and groups. Individuals, including perceived experts and online celebrities, often blur the lines of medical authority, leveraging their influence to spread misinformation (Harris et al., 2024). Groups, such as the "disinformation dozen," play a significant role in disseminating large amounts of low-credibility content, affecting public trust, especially during pandemics (Herasimenka et al., 2023). Literature highlights that the collective actions of these groups can significantly amplify the impact of misinformation.

3.2 Target victims

In our conceptual analysis framework, the "target victims" dimension identifies the audience, individuals or groups that disinformation campaigns aim to harm (Zhang and Ghorbani, 2020). Understanding who the target victims are is essential for assessing the impact of misinformation and developing effective countermeasures. This study categorizes target victims based on patterns observed in prior research on anti-vaccine misinformation and broader disinformation strategies. The classification reflects both the frequency and strategic intent behind misinformation campaigns, with groups positioned based on their societal roles and the nature of their targeting.

1 *Activist groups* are often targeted because they advocate for social, political, or legal changes, making them a frequent focus of actors seeking to discredit or disrupt movements (Shahid et al., 2022). Their visibility and engagement in public discourse make them susceptible to misinformation designed to erode trust in their causes.
2 *Individual victims* can also be directly targeted, whether they are part of online communities or not. Smear campaigns frequently focus on single persons, aiming to damage their reputations and delegitimize their work (Lee, 2018). This includes journalists, scientists, and public figures whose influence threatens misinformation narratives.
3 *Political entities*, including political parties and politicians, are another major category of victims. Disinformation campaigns often seek to manipulate electoral outcomes or erode public trust in governance by spreading false information about political figures (Shahid et al., 2022). Given the direct impact of political misinformation on democratic processes, these actors are consistently targeted.
4 *Scientific and medical communities* face significant targeting, particularly in the context of health misinformation. During the COVID-19 pandemic, researchers and medical professionals were frequently attacked to undermine public trust in vaccines and health measures. The spread of false information about scientific institutions is often intended to delegitimize expertise and promote alternative, misleading narratives.
5 *Social identity groups*, defined by characteristics such as race, ethnicity, gender, social class, sexual orientation, or religious beliefs, are frequent targets of misinformation designed to deepen societal divisions. By exploiting existing tensions, malicious actors can manipulate public opinion and behavior, reinforcing polarization and hostility (Shahid et al., 2022; Lee, 2018).

This categorization balances specificity with comprehensiveness, ensuring that the analysis captures the primary ways misinformation operates across different societal domains. The order reflects a progression from structured organizations (activist and political groups) to individual and institutional targets, concluding with the broadest category—social identity groups—whose targeting has wide-ranging implications for societal cohesion.

3.3 Message content

As part of our conceptual analysis framework, the dimension of "message content" encompasses both linguistic and visual semiotic resources employed in disinformation campaigns to engage and mislead audiences. In this context, visual elements, such as images, typography, layout, and design choices, function as salient

communicative modes that shape how users perceive and interact with misinformation (van Leeuwen, 2005; Kress and van Leeuwen, 2006). These multimodal resources contribute to the persuasive power of disinformation by directing attention, evoking emotions, and reinforcing ideological frames.

A particularly relevant feature is attention-capturing strategies, including clickbait headlines, hashtags, and image-text juxtapositions (Lee, 2018). These elements, often strategically designed to trigger curiosity or emotional reactions, align with Dimitrova's (2011) work on media framing and visual priming, where the presentation of information significantly influences audience interpretation. For instance, the use of provocative headlines or manipulated images can frame misinformation in a way that enhances its credibility and virality.

In most cases, the actors in the anti-vaccination movement employ a multimodal content strategy that includes text, images, audio, video and interactive elements, making their messages accessible and engaging (Wawrzuta et al., 2021). Several tactics include document manipulation, which involves creating misinfographics and recontextualizing media to mislead audiences (Harvard Kennedy School Shorenstein Center on Media, Politics and Public Policy, 2023). Additionally, evidence collage compiles information from multiple sources into a single document to persuade the target audience, while distributed amplification involves campaign operators directing participants to widely disseminate materials, complicating mitigation efforts and overwhelming the information ecosystem (Krafft and Donovan, 2020).

Research indicates that the effectiveness of disinformation is less about the dissemination of technologies and more about the emotional and cognitive reactions they evoke (Martel et al., 2020; Horner et al., 2023). Cognitive biases and societal influences play significant roles in how misinformation is perceived and retained, making it essential to address these aspects in combating misinformation. Hence, the visual content includes opinions and sentiments that create polarity and influence views through trolling, memes, and viral slogans. This content leverages strong emotional appeals to make messages more sensational and memorable (Wawrzuta et al., 2021). Anti-vaccination discourse often involves narrative persuasion, where storytelling is used to engage audiences more effectively than factual arguments, reducing critical thinking and increasing susceptibility to misinformation (Covolo et al., 2017). Emotional appeals and personal stories attract attention and can lead to inaction regarding vaccination by leveraging fears and uncertainties (Guidry et al., 2015). Cultural values and personal freedom are emphasized to resonate with those skeptical of mainstream health information (Benecke and DeYoung, 2019), and anti-vaccine sites often imply false credibility or scientific authority to enhance their legitimacy (Davies et al., 2002).

Linguistic content will be analyzed through various dimensions to understand the themes and narratives used in misinformation. These dimensions include conspiracy theories, where misinformation involves elaborate conspiracy theories that undermine trust in official sources and institutions (Oliveira et al., 2022; Pierre, 2020). Political content can be politically motivated, aiming to influence public opinion or disrupt political processes (Sánchez-Castillo et al., 2023). Extremism promotes radical ideologies, while hate speech targets specific races, genders, religions, or political groups, inciting violence or discrimination (Koehler, 2023; Chen, 2024). Testimonials and captious language, such as using personal stories to elicit emotional reactions and sway opinions, often trap readers with subtly deceptive reasoning (DiResta, 2018). Emotion contagion manipulates emotions to trigger negative responses, and cloaked science uses scientific jargon to lend credibility to false claims (Herasimenka et al., 2023).

By leveraging both linguistic and visual semiotic resources, disinformation campaigns effectively manipulate audience perception and engagement. Future research should focus on cross-platform comparative analyses and the development of automated detection tools that account for the multimodal nature of disinformation. As digital media environments evolve, interdisciplinary approaches will be essential for mitigating the spread of misleading content and enhancing public resilience against information manipulation.

3.4 Social context

The social context of misinformation refers to the broader environment in which false or misleading information spreads. This encompasses the interaction between users, the technological landscape shaping information flows, and the political and societal conditions that influence how misinformation is produced, shared, and received. The social context is essential in understanding why misinformation gains traction, as it determines the speed, scale, and impact of false narratives across different communities and platforms (Castillo et al., 2011). One key aspect of social context is the interaction between users within digital communication spaces. Misinformation does not spread in isolation—it moves through networks of individuals, groups, and online communities where social relationships, trust dynamics, and engagement patterns determine its reach and persistence (Olteanu et al., 2018). Social media platforms and messaging applications structure these interactions through algorithms, content-ranking mechanisms, and platform-specific policies, all of which influence how information is shared, debated, and reinforced within different communities. Additionally, shifts in content moderation, changes in platform ownership, and evolving user norms can alter the ways misinformation circulates, making the temporal dimension of the social context a crucial factor to consider (Skafle et al., 2022).

The technological environment further shapes the social context of misinformation. The stage of technological development determines the tools available for creating, distributing, and countering misinformation. The rise of artificial intelligence, deepfake technology, and algorithmically driven content recommendation systems has transformed the landscape of misinformation, making it more sophisticated and difficult to detect (Martínez, 2023). Additionally, the increasing use of encrypted messaging apps, private forums, and decentralized platforms challenges traditional fact-checking and intervention efforts, as these environments offer reduced visibility and minimal content regulation (Cowden and Yuval-Davis, 2022).

Beyond digital infrastructure, the political and societal climate significantly influences misinformation dynamics. Certain periods, such as crises, elections, and contentious social debates, create conditions where misinformation spreads more rapidly and exerts greater influence. During crises, uncertainty and urgency drive people to seek information quickly, often before verification processes can take effect, making them more susceptible to false narratives (Clemente-Suárez et al., 2022). Election cycles amplify misinformation, as actors seeking to manipulate public opinion exploit digital platforms to shape perceptions, attack opponents, or suppress voter engagement (Seckin et al., 2024). Additionally, wedge issues—deeply divisive topics related to identity, ideology, or social policy—fuel

misinformation campaigns designed to deepen polarization and reinforce preexisting biases (Martínez, 2023).

By examining misinformation through the lens of social context, encompassing communication structures, technological development, and political conditions, researchers can better understand the factors that enable its spread and persistence. Addressing misinformation effectively requires approaches that account for how these contextual dimensions interact and evolve.

4 Testing the applicability of the conceptual framework

We assess the applicability of the conceptual framework by evaluating its utility within the context of the antivaccination community on Telegram. This section presents the methodology employed and the results obtained from this evaluation.

4.1 Methodology

4.1.1 Data collection and extraction methods

To test the applicability of our conceptual framework, we examined the antivaccination community on Telegram. We collected channels by searching Telegram with keywords such as "covid," "covid19," "vaccines," "anti-vax," "covid vaccination complications," "vaccine victims," "vaccine injuries," and "Pfizer." The data collection took place in December 2023. To ensure a comprehensive sample, we also employed a snowballing method, a well-established technique in Telegram research (Peeters and Willaert, 2022). This method assumes that if a channel forwards a message from another channel, a meaningful relationship exists between them. Additionally, Telegram channel links were retrieved from Facebook communities identified through similar keywords. Our web crawling efforts yielded an extended list of 151 channels. From these channels, we acquired all the messages, focusing on the first 50 messages from each channel. This resulted in a dataset of 7,550 messages, including original contributions in English and Lithuanian, as well as forwarded messages in English from international channels.

4.1.2 Data labeling approach

The messages were labeled according to the conceptual model discussed in Section 3, which includes the following categories: (1) *Features of spreaders/creators:* Malicious vs. Non-Malicious, Individual vs. Group, Human vs. Bot; (2) *Target victims*: activist, political, scientific/medical, minorities, undetermined; (3) *Message content*: linguistic (Conspiracy, Politics, Extremism, Hate speech, Captious language, Emotion contagious, Testimonial, Trolling, Others) and visual/multimodal strategies (Document manipulation, discourse manipulation, Evidence collage, distributed amplification, Cloaked science); and (4) *Social context*: active Crisis, Breaking News Event, Election Period, Wedge Issue. Three coders independently and manually labeled each message in the channel from March to May 2024. The subcategories were further detailed into smaller sections. The coding process was facilitated using Label Studio,[1] where annotators could tag channels and messages, and include comments and questions. Early annotation stages involved discussions among project members to refine the coding scheme. Up to 5% of messages were undefined and could not be analyzed. A codebook was maintained to document the annotations and any comments by annotators.

4.1.3 Statistical analysis

Profiling channels based on misinformation is a complex, resource-intensive process that needs not only clear definitions and reliable data but also reliable statistical analyses. To analyze the labeled messages, the statistical package JAMOVI, version 2.6.13 was applied. The sub-categories (e.g., non-malicious, activist, conspiracy, document manipulation, active crisis) were entered as variables, and the number of messages in each channel in each sub-category was entered as data. For the sub-category "malicious," a new variable was computed, summing up malicious creators, spreaders, and those that were labeled as undetermined. Based on the number of both labeled as malicious and non-malicious messages in all the channels ($n = 151$), a latent profile analysis was performed to test how many classes (profiles) can be identified in the whole sample of channels. Afterwards, differences between the identified classes of channels were analyzed concerning previously established four categories with a specific focus on subcategories.

4.1.4 Ethical considerations

All data collected were anonymized to protect the identities of individuals involved. Only public channels were accessed, with no attempts to enter private channels or chats. Messages, texts, and images shared on social media are considered part of the public domain. Data collected were publicly posted on Telegram, assuming that users expect the virtual space to be open to the public. However, channel names were replaced with codes to ensure privacy and ethical integrity.

4.2 Results

4.2.1 Preliminary analysis of data labeling approach

The preliminary analysis of the 7,550 messages from 151 anti-vaccination Telegram channels is structured around four primary dimensions: features of spreaders/creators, target victims, news content, and social context (Table A1).

Features of spreaders/creators: a significant number of messages were labeled as non-malicious (3,158), while 1,626 messages were identified as malicious. Only a few messages were classified as malicious creators (5) and none as malicious spreaders. It was challenging to differentiate between spreaders and creators based solely on message content, so the rest of the messages remained unclassified due to insufficient context. When distinguishing between individual and group actors, only six messages were identified as individual, and one as a group, with 553 remaining unclear. Similarly, identifying whether the actor was human or a bot was difficult, resulting in only four messages being labeled as human, none as bots, and 544 as unclear. The significant number of "unclear" labels highlights the difficulty in determining the nature of the spreader/creator without additional context.

Target victims were categorized as Activist, Political, Scientific/medical, Minorities, and Others. A considerable number of messages

1 https://app.heartex.com

could not be clearly labeled, indicating challenges in identifying the specific targets of disinformation campaigns. Only one message targeted activists, two targeted political entities, 14 targeted the scientific/medical community, and two fell into the "Others" category, leaving 1,611 messages undetermined. The predominance of "undetermined" labels suggests a need for more detailed content to accurately identify target victims.

Message content was divided into linguistic (text-based context) and visual/multimodal categories. Among the linguistic content, conspiracy theories (1,235), politics (105), and testimonials (141) were more frequently identified, whereas extremism (6) and hate speech (21) were less common. In the visual/multimodal category, evidence collages (1,194) and discourse manipulation (67) were prevalent, while cloaked science (17) and distributed amplification (25) were less frequently observed. While some categories like "Conspiracy" and "Evidence collage" had substantial data, others like "Extremism" and "Cloaked science" were less frequently identified, indicating variability in content types.

Social context was categorized as Active Crisis, Breaking News Event, Election Period, and Wedge Issue. Labeling in these contexts also presented challenges, with many messages lacking sufficient information to determine the context accurately. The analysis showed a higher frequency of messages related to active crises (1,117) and breaking news events (270), suggesting that disinformation campaigns often exploit these contexts. Wedge issues (218) and election periods (27) were less frequently identified but still significant.

4.2.2 Latent profile analysis

Latent Profile Analysis (LPA) was conducted to investigate unobserved heterogeneity in online content: based on the data of both labeled as malicious (1631) and non-malicious (3,158) messages in each channel, it was tested how many classes (profiles) can be identified in the whole sample of channels (n = 151). In this study, tidyLPA within JAMOVI 2.6.13 was used to explore a series of latent profile solutions. This package in R is designed to generate finite mixture models that identify unobserved subgroups (i.e., latent classes) based on continuous indicators. The models tested ranged to several classes, and it was focused on the best-fitting two-class solution according to a set of criteria. Multiple fit indices were considered, including the Akaike Information Criterion (AIC), Approximate Weight of Evidence (AWE), Bayesian Information Criterion (BIC), Classification Likelihood Criterion (CLC), Kullback Information Criterion (KIC), the sample-size-adjusted BIC (SABIC), and Integrated Completed Likelihood (ICL) to determine which of four competing two-class models offered the best balance of fit and parsimony. Table A2 displays the overall fit metrics for each model. In JAMOVI, the final selection of the model was guided by an analytic hierarchy process (AHP), a methodology that integrates multiple fit indices to recommend an optimal solution. The results indicated to selection of a model (Nr. 6) which achieves the smallest BIC (BIC = 2820.0), exhibits a comparatively high log-likelihood value (−1382.0), the lowest AIC (2786.0), the second-lowest SABIC (2785.0), and the most negative ICL (−2845.0), implying that this profiling provides a strong overall fit while retaining parsimony. Furthermore, in LPA, each participant receives a posterior probability of belonging to each latent class. For the final selected profiling model, the smallest of these average probabilities is 0.85522, and the largest is 0.93014, and these values signify that, on average, messages are assigned to their most likely class with an 85.5–93.0% probability, reflecting satisfactory classification quality. Additionally, the proportion of messages assigned to each class ranges from 0.38411 to 0.61589, providing a roughly 38–62% split in class sizes, indicating that neither class is disproportionately small, and reducing potential concerns about unstable solutions or spurious classes. Thus, this profiling model was chosen for all subsequent interpretation and reporting of parameter estimates, and this solution identified two latent classes, or profiles, each characterized by distinct estimates of the observed indicators (malicious and non-malicious messages) included in the analysis. Table 2 presents the final parameter estimates (i.e., means and variances) and associated statistics for both latent classes; in the context of LPA, the provided means are the model-estimated average values of each indicator (in this case, *Not malicious messages* and *Malicious messages*) for each of the two latent classes.

Latent Class 1 contains approximately 38.4% of the channels (specifically, 58 channels). This profile is characterized by lower scores on *Not malicious* (M = 30.40) content and higher scores on *Malicious* (M = 45.80) content. Latent Class 2 comprises roughly 61.6% of the total channels (specifically, 93 channels). In contrast to Class 1, Class 2 exhibits substantially higher *Not Malicious* content scores (M = 84.30) and lower *Malicious* scores (M = 23.40). Hence, Class 2 appears to have a much stronger inclination with *Not malicious* content and a diminished tendency toward *Malicious content* relative to the other group. Across both classes, the means of *Not malicious* and *Malicious* differ substantially in magnitude. Moreover, the standard errors (SE = 4.72–8.90) and the $p < 0.001$ suggest robust differences between the two classes. This distinction is supported by an entropy of 0.764, which falls into the range typically considered indicative of good separation in LPA, meaning that the classes are differentiated with relatively low misclassification error. Figure 2 demonstrates a line plot of latent profiles of Telegram channels based on anti-vaccination messages.

From a substantive perspective, the presence of two distinct classes suggests that the channels divide into a group that rates relatively high on *Malicious* and lower on *Not malicious* (Class 1) content, dimensions contrasted with a group showing the reverse

TABLE 2 Latent profile analysis: parameter estimates for the two-class solution for 151 channels.

Category	Parameter	Class 1		Class 2		*p*
		Mean	SE	Mean	SE	
Means	Not malicious messages	30.40	4.72	84.30	4.39	< 0.001
	Malicious messages	45.80	8.90	23.40	1.77	< 0.001
Variances	Not malicious messages	502.40	110.31	502.40	110.31	< 0.001
	Malicious messages	441.60	93.99	441.60	93.99	< 0.001

SE, Standard error.

pattern (Class 2), although LPA is an exploratory approach that does not, by itself, explain why these profiles emerge. Thus, the findings revealed the existence of two latent profiles in the data, distinguished primarily by their patterns on *Not malicious* and *Malicious* messages.

After establishing two latent classes via Latent Profile Analysis (LPA), an independent samples *T*-test was conducted to examine mean differences between Class 1 (n = 58) and Class 2 (n = 93) across a variety of variables. The *t*-test compared the actual observed values (e.g., Undetermined target, Active crisis, Breaking news events) recorded in the dataset for each channel in Class 1 vs. Class 2; the means provided below represent the average scores of messages when splitting dataset into two groups based on each channel's most likely class assignment and then computing regular descriptive statistics. Overall, several variables did yield statistically significant group differences between Class 1 and Class 2 (Table 3). Firstly, *the Undetermined target* was significantly higher in Class 1 (M = 46.33, *SD* = 28.58) exceeding Class 2 (M = 23.08, *SD* = 12.94). Another significant mean difference emerged for *Active crisis*: Class 1 (M = 39.34, *SD* = 31.64) was significantly higher than Class 2 (M = 11.51, *SD* = 11.75), also suggesting a very large effect. Although the effect size was more moderate, Class 1 (M = 3.69, *SD* = 5.87) scored lower on *Breaking news event*s than Class 2 (M = 6.41, *SD* = 7.08), (negative indicating Class 2 > Class 1). Class 1 scored lower (M = 1.22, *SD* = 2.17) than Class 2 (M = 2.63, *SD* = 3.66) on the *Type of activism: Politics*, indicating a moderate effect. However, Class 1 was substantially higher (M = 41.33, *SD* = 29.88) on *Type of activism: Conspiracy* relative to Class 2 (M = 14.05, *SD* = 11.50), this was one of the largest observed effects in the analysis. Class 1 also demonstrated higher means on *Trolling* (M = 1.64, *SD* = 4.98) than Class 2 (M = 0.16, *SD* = 0.47), as well as consistently higher scores on *Discourse manipulation* (e.g., *Cloaked science*, *Evidence collage*, *Captious language*, *Testimonial*). Notably, *Discourse manipulation: Evidence collage* had a large effect size, with Class 1 (M = 33.83, *SD* = 23.13) far exceeding Class 2 (M = 17.43, *SD* = 11.34). Class 1 also scored higher on *Identity Unclear* (M = 12.90) and *Human vs bot- Unclear* (M = 13.33) than Class 2 (M = 8.96 and 9.24, respectively). The rest of the comparisons, including those for various hate speech indicators, types of targeted groups, and other manipulation tactics, did not reach statistical significance (*p*s > 0.05) and these null results may indicate insufficient statistical power to detect smaller effects.

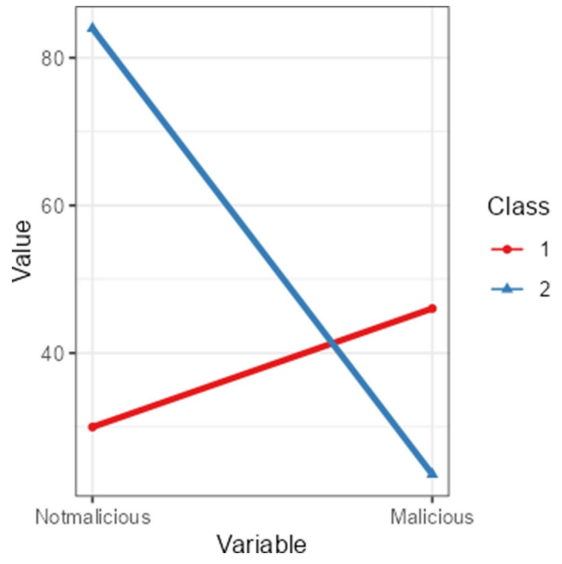

FIGURE 2
Latent profiles of Telegram channels based on anti-vaccination messages: line plot.

Overall, the *T*-test results indicate clear differences between the two latent classes in terms of misinformation characteristics and thematic emphasis. Class 1 demonstrates significantly higher scores in several key dimensions, including Undetermined target, Active crisis, Trolling, Conspiracy, Individual identity, and specific Discourse manipulation techniques such as Evidence collage, cautious language, and Testimonial strategies. These findings suggest that Class 1 is more engaged in deceptive, emotionally charged, and manipulative discourse, associated with conspiracy-driven narratives. The prominence of trolling and identity-based targeting in this class highlights a strategic use of misinformation aimed at provoking reactions, deepening divisions, or discrediting individuals and groups. In contrast, Class 2 displays lower or near-zero scores in these categories but is significantly more likely to reference Breaking news events and Political topics. This suggests that Class 2 may be more aligned with real-time information-sharing behaviors, focusing on current events rather than engaging in manipulative or deceptive tactics. However, while their references to political themes could be neutral or factual, further qualitative analysis would be necessary to determine whether this class also contributes to political misinformation or simply reacts to political discourse.

The large effect sizes observed across these variables underscore the pronounced differences between the two groups. These findings are particularly relevant because they validate the latent profile analysis (LPA)-derived classifications, confirming that the two latent profiles are not arbitrary but represent statistically meaningful distinctions in misinformation behaviors and themes. The fact that these distinctions hold across a subset of key variables suggests that each class represents a cohesive behavioral pattern, with Class 1 leaning toward manipulative, crisis-oriented, and conspiracy-driven content, while Class 2 focuses more on political and breaking news narratives.

The results of this study underscore the complexity and variability in anti-vaccination content on Telegram and highlight the need for refined analytical techniques and improved frameworks for categorizing and understanding misinformation.

5 Discussion

This study sheds light on the spread of misinformation within anti-vaccination Telegram channels, emphasizing both the utility and limitations of the applied conceptual framework. Identifying creators versus spreaders through message content alone was challenging, aligning with Leader et al. (2021) and many messages remained unclassified due to insufficient context, underscoring the need for more data that includes metadata and user behavior patterns. Similarly, identifying target victims was difficult, with many messages unclassified, as target victims are seldom explicitly mentioned (D'Ulizia et al., 2021), suggesting the necessity for additional context or integrated data sources. In terms of message content, conspiracy

TABLE 3 Independent samples *t*-test statistically significant results comparing Class 1 (n = 58) and Class 2 (n = 93).

Variable	*t* (149)	*p*	Mean diff.	SE diff.	95% CI (diff.)	Cohen's d	95% CI (d)
Features of spreaders/creators							
Individual identity	2.24	0.027	0.052	0.023	[0.006, 0.097]	0.37	[0.04, 0.70]
Identity: unclear	2.07	0.040	3.94	1.91	[0.17, 7.71]	0.35	[0.01, 0.68]
Human vs. bot - unclear	2.22	0.028	4.09	1.84	[0.45, 7.73]	0.37	[0.04, 0.70]
Number: unclear	2.23	0.027	4.15	1.86	[0.47, 7.82]	0.37	[0.04, 0.70]
Target victims							
Undetermined	6.82	< 0.001	23.25	3.41	[16.51, 29.99]	1.14	[0.79, 1.49]
Message content							
Trolling	2.84	0.005	1.48	0.52	[0.45, 2.50]	0.48	[0.14, 0.81]
Politics	−2.66	0.009	−1.41	0.53	[−2.46, −0.36]	−0.44	[−0.78, −0.11]
Conspiracy	7.92	< 0.001	27.27	3.44	[20.47, 34.08]	1.33	[0.96, 1.68]
Cloaked science	2.08	0.039	0.31	0.15	[0.02, 0.60]	0.35	[0.02, 0.68]
Evidence collage	5.81	< 0.001	16.40	2.82	[10.82, 21.97]	0.97	[0.63, 1.32]
Captious language	2.30	0.023	0.47	0.21	[0.07, 0.88]	0.38	[0.05, 0.72]
Testimonial	4.38	< 0.001	4.11	0.94	[2.26, 5.97]	0.73	[0.39, 1.07]
Discourse manipulation, overall	2.72	0.007	1.53	0.56	[0.42, 2.65]	0.45	[0.12, 0.79]
Social context							
Breaking news event	−2.45	0.016	−2.72	1.11	[−4.91, −0.52]	−0.41	[−0.74, −0.08]
Active crisis	7.69	< 0.001	27.84	3.62	[20.69, 34.99]	1.29	[0.93, 1.64]

Negative *t*-values and negative mean differences indicate higher means for Class 2 than Class 1. CI, Confidence Interval. The mean difference reflects (Class 1–Class 2). Omitted rows represent variables for which $p > 0.05$.

theories and evidence collages were prevalent, reflecting Wawrzuta et al. (2021), with the significant presence of emotional appeals and personal stories indicating the psychological dimensions of misinformation, which require targeted strategies to address. Misinformation frequently exploits active crises and breaking news events, leveraging high public interest and uncertainty to spread rapidly, making it crucial to understand these contexts for developing timely, context-specific interventions. Another key finding is the distinction between malicious and non-malicious misinformation channels, which became evident through latent profile analysis (LPA) and *t*-test results. These findings suggest that misinformation can have different forms—some actors actively manipulate narratives for ideological or disruptive purposes, while others participate in information-sharing with varying degrees of accuracy and intent.

Based on the statistically significant comparisons between the channels, several clear patterns emerge:

5.1 Features of creators/spreaders

Class 1, which can be described as a more malicious profile, reported higher levels of ambiguous or unclear identity of spreaders/creators (Individual Identity, Identity: Unclear, Human vs. bot: Unclear, Number: Unclear). Although modest in magnitude (d = 0.35–0.37), these findings suggest Class 1 misinformation may stem from (or emphasize) uncertain, difficult-to-trace sources. The literature review highlights that humans' inability to distinguish bots from real accounts leads to the inadvertent spreading of misinformation (Torabi Asr and Taboada, 2019; Schlette et al., 2022; Rogers, 2020; Vosoughi et al., 2018). The results highlight the importance of engagement metrics, timestamps, and interaction patterns in distinguishing between malicious and non-malicious misinformation actors. Analyzing content alone is insufficient for differentiating between systematic disinformation efforts and organic information-sharing.

5.2 Target victims

"Undetermined" target victims showed one of the largest gaps (d = 1.14), indicating Class 1 (more malicious profile) content is significantly more likely to remain vague about intended targets or victims. The results differ from previous research (Lee, 2018; Shahid et al., 2022), where clear strategic intents toward different audience groups were identified. Since the target audience is rarely explicitly mentioned, expanding the framework to include cross-platform data sources or indirect signals of targeting can improve accuracy. Malicious channels, in particular, exhibited higher engagement in identity-based misinformation, suggesting the need for better indicators of implicit targeting strategies.

5.3 Message content

Conspiracy content emerged as a major distinction (d = 1.33), as Class 1, a more malicious profile, is substantially more likely to include conspiratorial messages. Evidence collage (d = 0.97), Testimonial framing (d = 0.73), and Cloaked science (d = 0.35) likewise appear

more frequently in Class 1. Trolling (d = 0.48) and Captious language (d = 0.38) are also higher in Class 1, suggesting more confrontational or misleading rhetorical strategies in a more malicious profile. In contrast, Politics (d = −0.44) is higher in Class 2, implying that politically oriented messaging is more central to Class 2 (less malicious) than Class 1. The results are in alignment with other studies, which claim that anti-vaccination movements employ multimodal content strategies and document manipulation (Wawrzuta et al., 2021; Krafft and Donovan, 2020; Martel et al., 2020; Horner et al., 2023).

5.4 Social context

Active crisis (d = 1.29) is strongly elevated in Class 1, consistent with the large effect sizes seen for conspiracy-related messages (in alignment with the results of Clemente-Suárez et al., 2022; Seckin et al., 2024). However, Breaking news events (d = −0.41) are more characteristic of Class 2, indicating that Class 2 (less malicious) communications are likelier to connect to immediate, unfolding events. Less malicious Class 2 content, meanwhile, tends more toward political discussion and references to breaking news. These findings suggest two qualitatively distinct styles or "profiles" of misinformation/disinformation activity. Given that misinformation spreads differently depending on the social and political climate, the framework should incorporate real-time contextual factors, such as ongoing crises, election cycles, and wedge issues. This would allow for dynamic misinformation tracking, that accounts for how malicious actors exploit high-interest events to amplify false narratives. Lastly, since malicious channels exhibited significantly different engagement strategies compared to non-malicious ones, refining the framework by incorporating behavioral markers of coordinated activity (e.g., bot-like posting patterns, repeated message forwarding) can improve classification precision.

Our study has several limitations. Focusing solely on public Telegram channels may overlook significant misinformation activities occurring in private or semi-private groups, which often serve as key vectors for misinformation spread. Additionally, reliance on message content alone limited our ability to capture underlying intent and actor motivations, highlighting the need for metadata and engagement pattern analysis. The manual annotation process, while thorough, was also time-consuming and subject to potential bias, emphasizing the importance of automated detection tools in future research.

The dynamic nature of misinformation, especially within malicious channels, further underscores the need for continuous updates to the framework. The significant differences identified between the two classes suggest that countermeasures may need to be tailored accordingly, for example, addressing conspiracy-driven content with credibility-based interventions, while managing breaking news misinformation through real-time verification efforts. Misinformation tactics evolve rapidly, often in response to current events, fact-checking efforts, and platform policies, requiring adaptive methodologies that can detect emerging manipulation strategies in real time. Future research should compare malicious and non-malicious misinformation sources using cross-platform analyses, integrating verified medical news sources as control data to enhance reliability in identifying misinformation.

6 Conclusion

This study offers an in-depth examination of the role Telegram plays in the dissemination of misinformation, focusing on the methodological challenges and the development of a conceptual framework for profiling malicious channels. By addressing the unique features of Telegram, such as its end-to-end encryption and the diversity of its communication channels, this research highlights the complexity of tracking and analyzing misinformation on this platform. Malicious channels exhibit higher engagement with crisis-driven misinformation, conspiratorial content, trolling, vague or unidentifiable sources, and undetermined targeting. They rely on discourse manipulation techniques such as Evidence Collage, Captious Language, and Testimonial Strategies, indicating a deliberate intent to mislead. Malicious channels tend to promote deceptive, misleading, or manipulative content, often including conspiracy theories, fabricated claims, or highly emotional narratives designed to provoke strong reactions. Malicious channels often use trolling, inflammatory rhetoric, or fear-based messaging to encourage engagement.

In contrast, not-malicious channels primarily focus on Breaking News Events and Political discussions, with minimal use of deceptive framing or manipulative discourse. Not-malicious channels focus on factual reporting, discussion, or opinion-sharing without intentional distortion. Non-malicious channels have more organic dissemination patterns, with less frequent resharing of misleading content and a greater emphasis on original analysis or discussion. They are more likely to cite sources, provide context, and use measured language, even when discussing controversial topics.

The statistical findings confirm large-effect differences between the two groups, supporting the need for context-specific misinformation detection strategies. Identifying patterns in manipulation techniques, crisis exploitation, and engagement behaviors can enhance misinformation mitigation efforts, allowing for more targeted fact-checking and content moderation approaches.

Future work will focus on refining data collection methods, integrating metadata and user behavior analysis using AI, and continuously updating the framework to adapt to evolving misinformation tactics. This approach will contribute significantly to safeguarding information integrity in digital spaces.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical approval was not required for the study involving human data in accordance with the local legislation and institutional requirements. Written informed consent was not required, for either participation in the study or for the publication of potentially/indirectly identifying information, in accordance with the local legislation and institutional requirements. The social media data was accessed and analyzed in accordance with the platform's terms of use and all relevant institutional/national regulations.

Author contributions

AS: Writing – review & editing. MM: Writing – original draft, Writing – review & editing. AD: Writing – original draft. GG: Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

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Appendix

TABLE A1 Descriptive analysis of labeled dataset (source: Authors, 2024).

Actors		Target		Content		Context	
Non-malicious	3,158	Activist	1	Non-physical		Active crisis	1,117
Malicious	1,626	Political	2	Conspiracy	1,235	Wedge issue	218
Malicious creator	5	Scientific/medical	14	Politics	105	Breaking news event	270
Malicious spreader	0	Minorities	0	Extremism	6	Election period	27
Individual	6	Others	2	Hate speech	21		
Group	1	Undetermined	1,611	Testimonial	141		
Unclear	553			Captious language	36		
Human	4			Emotion contagious	30		
Bot	0			Others	93		
Unclear	544			*Physical*			
				Document manipulation	41		
				Discourse manipulation	67		
				Evidence collage	1,194		
				Distributed amplification	25		
				Cloaked science	17		

TABLE A2 Latent profile analysis of channels (n = 151): the overall fit metrics for each model.

Model	Classes	Logik	AIC	AWE	BIC	CAIC	CLC	KIC	SABIC	ICL	Entropy
1	2	−1425	2863	2939	2884	2891	2850	2873	2862	−2920	0.665
2	2	−1401	2819	2917	2846	2855	2803	2831	2818	−2874	0.724
3	2	−1422	2860	2947	2885	2893	2846	2871	2859	−2926	0.615
6	2	−1382	2786	2906	2820	2831	2766	2800	2785	−2845	0.764

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Unravelling the infodemic: a systematic review of misinformation dynamics during the COVID-19 pandemic

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Introduction: The COVID-19 pandemic triggered not only a public health crisis but also a parallel "infodemic"—an overwhelming flood of information, including false or misleading content. This phenomenon created confusion, mistrust, and hindered public health efforts globally. Understanding the dynamics of this infodemic is essential for improving future crisis communication and misinformation management.

Methods: This systematic review followed PRISMA 2020 guidelines. A comprehensive search was conducted across PubMed, Scopus, Web of Science, and Google Scholar for studies published between December 2019 and December 2024. Studies were included based on predefined criteria focusing on COVID-19-related misinformation causes, spread, impacts, and mitigation strategies. Data were extracted, thematically coded, and synthesized. The quality of studies was assessed using the AMSTAR 2 tool.

Results: Seventy-six eligible studies were analyzed. Key themes identified included the amplification of misinformation via digital platforms, especially social media; psychological drivers such as cognitive biases and emotional appeals; and the role of echo chambers in sustaining false narratives. Consequences included reduced adherence to public health measures, increased vaccine hesitancy, and erosion of trust in healthcare systems. Interventions like fact-checking, digital literacy programs, AI-based moderation, and trusted messengers showed varied effectiveness, with cultural and contextual factors influencing outcomes.

Discussion: The review highlights that no single strategy suffices to address misinformation. Effective mitigation requires a multi layered approach involving reactive (fact-checking), proactive (digital literacy, community engagement), and structural (policy and algorithm transparency) interventions. The review also underscores the importance of interdisciplinary collaboration and adaptive policies tailored to specific sociocultural settings.

KEYWORDS

infodemic, misinformation, COVID-19, pandemics, health communication, social media, public health, epidemiology

Introduction

The COVID-19 pandemic not only posed a significant challenge to global healthcare systems but also gave rise to an unprecedented surge in misinformation, termed an "infodemic." (Clemente-Suárez et al., 2022). This phenomenon, characterized by an overabundance of information—both accurate and false—created confusion, fear, and

mistrust among the public (Infodemic, 2020). This study explores the factors driving COVID-19 misinformation, its spread via social media, its impact on public health, the effectiveness of mitigation efforts, and strategies to enhance resilience against misinformation in future health crises. Misinformation spreads through a structured process with multiple stages. Each stage influences how false information gains attention and persists.The spread begins with a source. This could be an individual, a social media post, or a coordinated disinformation campaign. The source may include manipulated content, misinterpretations, or deliberate fabrications. These false narratives are often designed to shape public opinion. Once misinformation is introduced, amplification occurs. Social media algorithms and human behavior contribute to its rapid spread. Emotionally charged misinformation spreads faster than factual content. This happens because social media platforms prioritize engagement and virality over accuracy. As misinformation spreads, it enters echo chambers. In these closed networks, people mainly interact with like-minded individuals. This limits their exposure to corrective information. As a result, misinformation becomes more persistent and harder to correct.To counter misinformation, intervention points are necessary. Real-time fact-checking, algorithm adjustments, and trusted messengers can help correct falsehoods. Healthcare professionals and community leaders play an important role in spreading accurate information. Digital literacy programs also help individuals assess the credibility of online content.The impact of misinformation depends on the effectiveness of interventions. If unchecked, false narratives continue to spread. However, timely corrections can increase public awareness and reduce the spread of misinformation. Understanding these processes helps in developing better strategies for preventing misinformation (Figure 1).Misinformation prevention involves multiple layers of intervention. The first layer focuses on reactive measures. Fact-checking and content moderation help counter misinformation after it has spread. Organizations verify claims, and AI systems flag or remove misleading content. However, these methods often face delays. People who already believe misinformation may also resist corrections. The second layer includes proactive strategies. These aim to stop misinformation before it spreads widely. Digital literacy programs teach people to evaluate information critically. Trusted messengers, like healthcare experts, help spread accurate information. The success of these strategies depends on cultural factors and people's pre-existing beliefs. The third layer addresses structural solutions. This includes government regulations and AI-driven moderation. Some governments have introduced laws to hold social media platforms accountable. AI systems are also used to detect misinformation early. However, these measures must balance misinformation control with concerns about censorship and algorithmic biases. Regulations also vary across different countries. The final goal is to reduce misinformation and strengthen public resilience. Combining reactive, proactive, and structural interventions creates a more effective and sustainable response. Continuous research, policy improvements, and collaboration across different sectors are necessary. This will help address the evolving challenges of misinformation (Figure 2). The spread of misinformation during the pandemic created many challenges for public health. It made existing problems worse and reduced people's willingness to follow preventive measures. As a result, governments and healthcare organizations struggle to provide accurate and timely information. This added pressure made it harder to manage the crisis effectively (Kisa and Kisa, 2024). The novelty of this study is that it takes an interdisciplinary approach by combining psychology, technology,

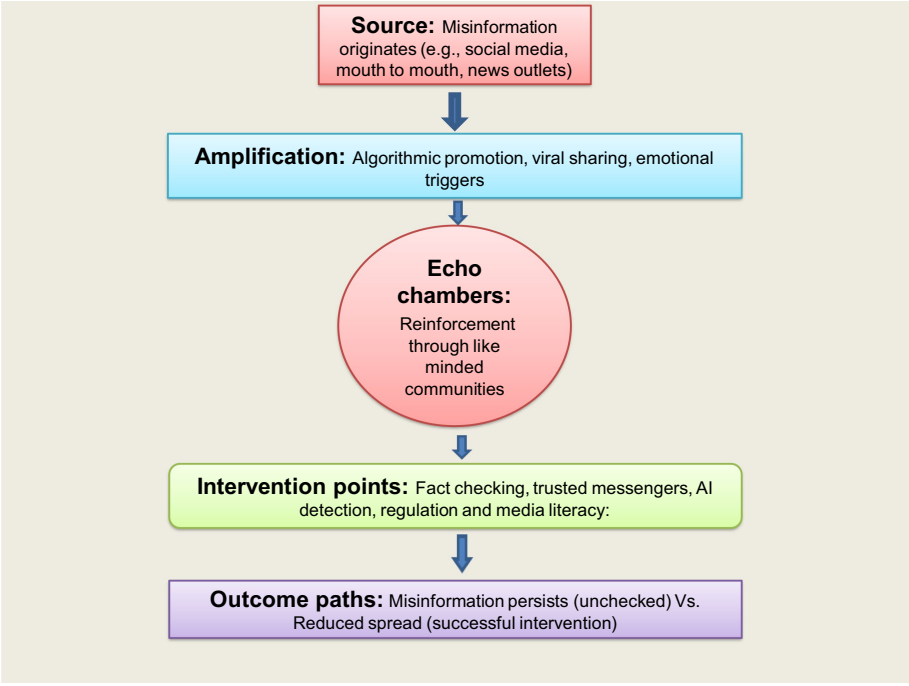

FIGURE 1
Misinformation spreading model.

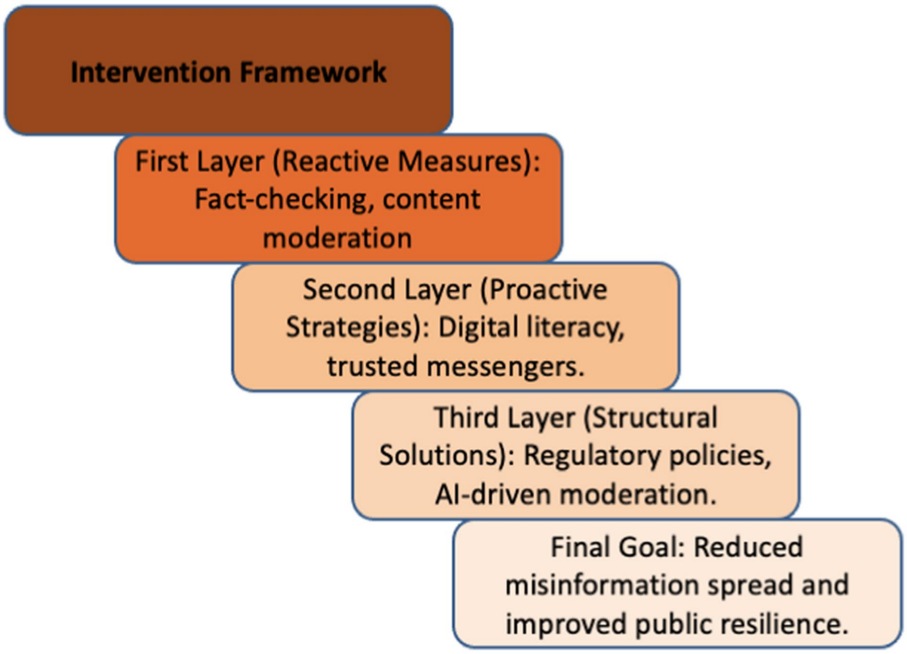

FIGURE 2
Intervention framework of misinformation prevention.

and policy. It goes beyond public health-focused research by using a structured framework to analyze misinformation. Unlike previous studies, it highlights algorithmic transparency and content amplification. It also explores advanced solutions like AI-based detection and blockchain verification. These insights offer new ways to manage misinformation effectively. Addressing this infodemic became a crucial priority to mitigate its impact on the pandemic response and recovery (Ferreira Caceres et al., 2022; Bhattacharya et al., 2021; Rodrigues et al., 2024). Historically, misinformation has been a recurring challenge during health crises (Kisa and Kisa, 2024; Rodrigues et al., 2024). For instance, during the 1918 influenza pandemic, unfounded claims about cures and conspiracy theories about the origins of the virus proliferated through newspapers and word of mouth (Barry, 2004). Similarly, the Ebola outbreaks in West Africa saw widespread myths about the disease, leading to harmful practices like avoiding healthcare facilities (WHO, 2020b; Muzembo et al., 2022; Buseh et al., 2015). However, the COVID-19 infodemic was unique in its scale and intensity, driven by the global reach of digital platforms and the unprecedented speed of information dissemination (Pulido et al., 2020; WHO, 2020a). Understanding this phenomenon is critical for addressing future infodemics in an increasingly interconnected world.

Aim

The aim of this systematic review is to synthesize the existing body of literature on the infodemic during the COVID-19 pandemic, with a focus on identifying its causes, manifestations, and implications, as well as the strategies employed to combat it.

Methodology

The review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 and the Quality of Reporting of Meta-analyses statement (Page et al., 2021). We explored the following research questions: 1. What were the key psychological, technological, and societal factors contributing to the spread of misinformation during the COVID-19 pandemic? 2. How did social media algorithms influence the amplification and dissemination of COVID-19 misinformation? 3. What were the public health consequences of misinformation on vaccine hesitancy and adherence to preventive measures? 4. How effective were fact-checking initiatives, regulatory measures, and public education campaigns in mitigating misinformation? 5. What strategies can improve public resilience against misinformation in future health crises?

Inclusion and exclusion criteria

The search terms were oriented according to the Population, Intervention, Comparison and Results (PICOS) approach, as shown in Table 1. Studies published between December 2019 and the present were included to ensure that the research focused on misinformation during the COVID-19 pandemic. Language: Only studies published in English were considered due to accessibility and consistency in analysis. Peer-reviewed journal articles, conference papers, and reputable preprints were included to ensure academic rigour. Studies specifically examining misinformation related to COVID-19, including its sources, spread mechanisms, psychological and social impacts, and mitigation strategies, were included. Studies published before December 2019 was excluded as they do not pertain to COVID-19

TABLE 1 Approach to study selection (PICO) following a systematic search.

Description	Abbreviation	Question components
Population	P	General public, including vulnerable populations, affected by misinformation during the COVID-19 pandemic.
Intervention	I	Strategies to combat misinformation, such as fact-checking initiatives, social media regulations, public education campaigns, and community-based interventions.
Comparison	C	Lack of intervention or existing misinformation without mitigation efforts.
Outcomes	O	Reduction in misinformation spread, increased public trust in health information, improved adherence to public health measures, and enhanced digital/media literacy.

misinformation. Non-English studies were excluded due to language barriers and potential translation inconsistencies. Opinion pieces, editorials, blog posts, and non-peer-reviewed sources were excluded to maintain academic reliability. Studies that addressed misinformation in general but did not specifically focus on COVID-19 were excluded from the review.

Search methods

We designed the search strategy with an information specialist using medical subject headings and specific keywords (Table 2). We included articles published in English from December 2019 to December 2024, focusing on the infodemic during the COVID-19 pandemic. Non-English papers were excluded due to language bias, resource constraints for translation, limited accessibility, and inconsistent quality control across languages, which may affect the reproducibility and comparability of findings. We searched four databases (PubMed, Scopus, Web of Science, and Google Scholar) and explored the included studies reference lists. Potential limitations of including only these four databases can include database, exclusion of grey literature, publication bias and indexing limitations. Boolean operators like AND is used to narrow a search by including all specified terms, ensuring that results contain each keyword and OR is used to broaden a search by retrieving results that contain at least one of the specified terms. We first conducted the search on 4 December 2024, and we re-ran the search on 6 Jan 2024. After removing duplicates, two authors independently screened the title, abstract and full text of articles and included eligible articles for evaluation. An independent third author resolved any disagreements. We performed the screening process in Gurugram (Gurugram, Haryana, India).

TABLE 2 Search strategy.

Database	Search String
PubMed	("COVID-19" OR "Coronavirus" OR "SARS-CoV-2") AND ("misinformation" OR "disinformation" OR "fake news" OR "infodemic" OR "false information") AND ("social media" OR "news media" OR "information spread" OR "viral misinformation") AND ("fact-checking" OR "trust" OR "belief" OR "public perception" OR "media literacy")
Scopus	TITLE-ABS-KEY ("COVID-19" OR "Coronavirus" OR "SARS-CoV-2") AND ("misinformation" OR "disinformation" OR "fake news" OR "infodemic" OR "false information") AND ("social media" OR "news media" OR "information spread" OR "viral misinformation") AND ("fact-checking" OR "trust" OR "belief" OR "public perception" OR "media literacy")
Web of Science	TS=("COVID-19" OR "Coronavirus" OR "SARS-CoV-2") AND TS=("misinformation" OR "disinformation" OR "fake news" OR "infodemic" OR "false information") AND TS=("social media" OR "news media" OR "information spread" OR "viral misinformation") AND TS=("fact-checking" OR "trust" OR "belief" OR "public perception" OR "media literacy")
Google Scholar	"COVID-19" OR "Coronavirus" OR "SARS-CoV-2" AND "misinformation" OR "disinformation" OR "fake news" OR "infodemic" OR "false information" AND "social media" OR "news media" OR "information spread" OR "viral misinformation" AND "fact-checking" OR "trust" OR "belief" OR "public perception" OR "media literacy"

Data collection and analysis

Two independent researchers extracted the general characteristics of each study and classified them into seven major themes: 1. The Role of Digital Platforms in Amplifying Misinformation, 2. Interventions to Combat the Infodemic. 3. The Role of Trusted Messengers 4. Proactive Regulation of Digital Platforms, 5.Enhancing Health and Media Literacy, 6.Bridging the Digital Divide, 7.Technological Innovations in Misinformation Management. We clustered articles based on similar properties associated with the stated objective and the reported outcomes. Although infodemics were primarily defined as the overabundance of information, usually with a negative connotation, we decided to report data from articles that also described the potential beneficial effects of the massive circulation of information and knowledge during health emergencies. We summarised the challenges and opportunities associated with infodemics and misinformation. A third author verified the retrieved data, and another author resolved any disagreements between the inter-reviewers.

Assessment of methodological quality

Two authors independently appraised the quality of the included articles using the AMSTAR 2 tool, which consists of 16 domains (Shea et al., 2017). Both reviewers conducted the screening and data extraction independently and in a blinded manner to minimize bias. Each categorical domain was rated using an online platform, and an overall assessment of critical and non-critical domains was obtained. Any inter-rater discrepancies were initially resolved through

discussion, and if consensus could not be reached, a third reviewer was consulted for arbitration.

Data extraction

Data extraction followed a clear and structured process, with records initially identified through database searches and additional sources such as hand-searching and references. The PRISMA Flow Diagram outlined the screening process, beginning with 495 records identified through database searches, with an additional 127 duplicate records from other sources. After removing duplicates, 495 records were screened for relevance based on title and abstract. Of these, 310 were excluded because 216 were found to be irrelevant to the research topic, 48 were excluded due to language and accessibility barriers, and 46 lacked empirical data. Following this step, 185 reports were sought for retrieval, but 27 could not be accessed, leaving 158 reports for eligibility assessment.

At the eligibility stage, a detailed evaluation of the 158 reports was conducted, leading to the exclusion of 82 reports. These were removed due to inappropriate study design (Ahmed et al., 2020), lack of an integrated study (Islam et al., 2020), or lack of relevance to the research objectives (Guess et al., 2020). After this rigorous selection process, 76 studies met the inclusion criteria and were incorporated into the final review. The diagram visually represents the systematic approach used in study selection, ensuring transparency and reproducibility in the research process (Figure 3).

Data synthesis

A narrative synthesis approach was used to categorize studies into key themes: misinformation spread, impact, and mitigation. Findings were analyzed thematically, integrating qualitative insights and quantitative summaries. Contradictory results were examined for methodological or contextual variations. Intervention

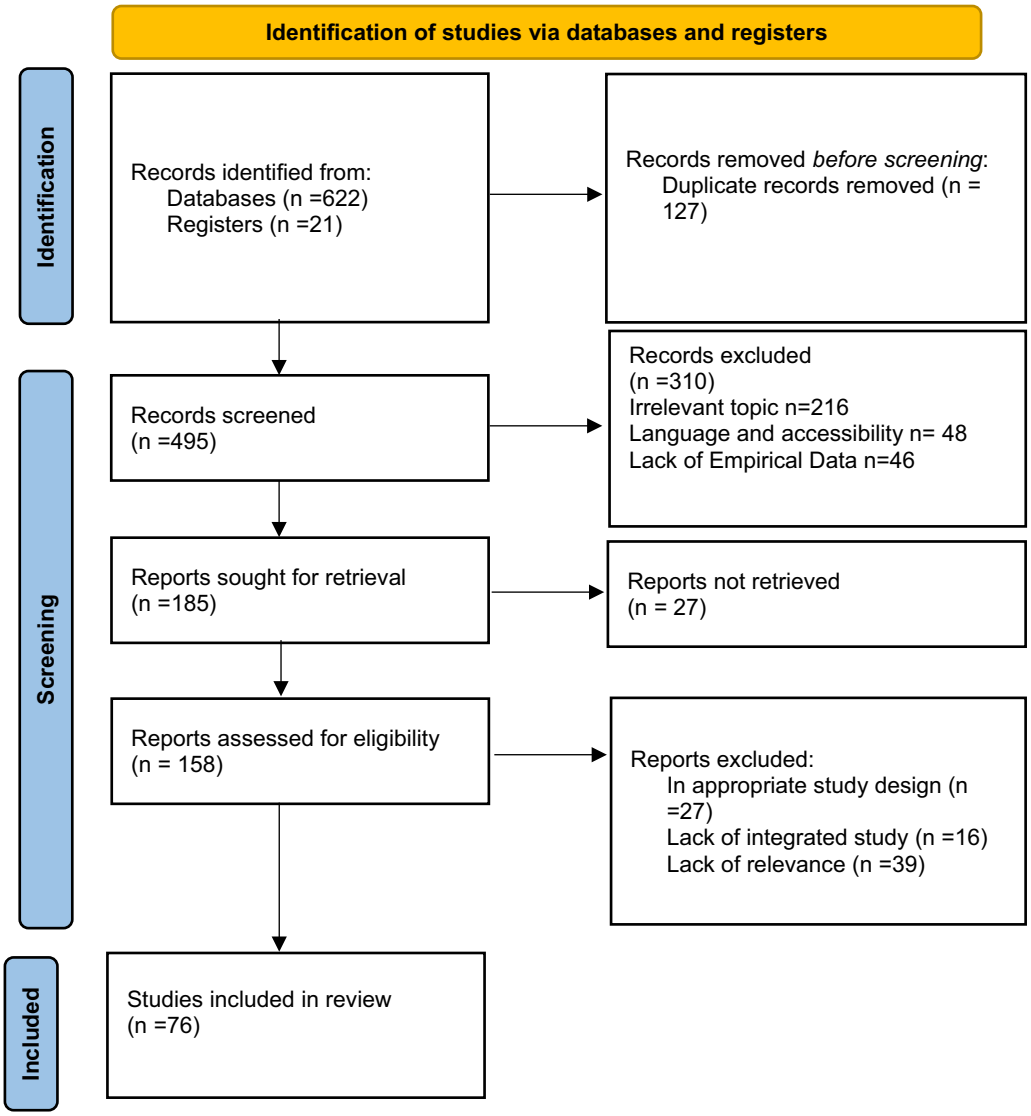

FIGURE 3
PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only.

effectiveness—fact-checking, media literacy, and regulations—was compared across studies. Insights were mapped to existing misinformation frameworks, providing a comprehensive understanding of its dynamics and implications.

Results

The results of this review revealed that the COVID-19 infodemic manifested through various channels, including social media platforms, traditional news outlets, and interpersonal communication (Kisa and Kisa, 2024; Pulido et al., 2020). Social media emerged as a dominant vector for the dissemination of misinformation, with platforms such as Facebook, Twitter, and YouTube playing pivotal roles. For instance, Joseph et al. analyzed millions of posts across platforms and highlighted that misinformation on COVID-19 was shared at a rate comparable to factual information, often reaching large audiences due to algorithmic amplification (Joseph et al., 2022).

Common themes of misinformation included the origins of the virus, prevention and treatment measures, vaccine safety and efficacy, and conspiracy theories. For example, Islam et al. (2020) identified over 2,300 rumours, stigma, and conspiracy theories circulating across 87 countries, with a significant proportion related to unverified treatments such as ingesting disinfectants or using herbal remedies (Islam et al., 2020). This misinformation not only fuelled public confusion but also led to direct harm; a study by Aghababaeian et al. reported over 700 deaths and thousands of hospitalizations in Iran due to methanol poisoning linked to false beliefs about its protective effects against COVID-19 (Aghababaeian et al., 2020).

Empirical studies also highlighted the adverse effects of the infodemic on public health outcomes. Ferreira Caceres et al. found that exposure to COVID-19 misinformation significantly reduced adherence to preventive measures such as mask-wearing and social distancing (Ferreira Caceres et al., 2022). Health misinformation significantly erodes trust between patients and healthcare professionals, leading to scepticism about medical advice. This distrust negatively impacts patient adherence to treatments and public health measures (Kbaier et al., 2024). Health misinformation significantly undermines public trust in credible health sources due to insufficient health and digital literacy among users, which is exacerbated by socio-economic disparities. A study explored the long-term impact of an Israeli government digital literacy program for disadvantaged populations, as perceived by participants 1 year after course completion. Interviews conducted a year later revealed that participants primarily joined the program out of cognitive interest, particularly to learn internet applications, followed by career aspirations. Reported benefits included increased knowledge, greater confidence in using technology, empowerment, and improved self-efficacy. However, participants noted that without ongoing practice or instructor support, much of the acquired knowledge diminished over time, affecting the program's lasting impact (Lev-On et al., 2020). Additionally, cultural contexts influence the reception of misinformation, making certain demographics more vulnerable (Ismail et al., 2022). Similarly, a survey by Pertwee et al. revealed that vaccine hesitancy increased in populations frequently exposed to anti-vaccine narratives online, with specific claims about microchip implantation and infertility driving mistrust in vaccine campaigns (Pertwee et al., 2022). The infodemic disproportionately affected vulnerable populations. For example, literacy barriers were evident in communities where access to credible sources of information was limited. A study conducted by Gaysynsky et al. demonstrated that individuals with lower health literacy were more likely to believe and share misinformation, exacerbating disparities in health outcomes (Gaysynsky et al., 2024). Vulnerable populations, particularly those in rural areas or low-income settings, were also found to be more susceptible to believing in conspiracy theories due to limited access to verified information sources (Kisa and Kisa, 2024) Quantitative analyses underscored the scale of the problem. Li et al. (2020) found that 25% of COVID-19-related YouTube videos contained misleading information, collectively amassing over 62 million views (Li et al., 2020). A similar study by Gallotti et al. (2020) reported that up to 40% of COVID-19-related tweets contained misinformation, often driven by bots and coordinated campaigns. Specific case studies, such as the "Pandemic" documentary, exemplify how misinformation campaigns gained traction and sowed widespread skepticism regarding public health interventions (Gallotti et al., 2020). Furthermore, Jon Agley and Yunyu Xiao identified a strong correlation between the virality of misinformation and public mistrust in health authorities, further complicating the pandemic response (Agley and Xiao, 2021). Localized examples also illustrate the impact of the infodemic. In India, misinformation about cow urine as a COVID-19 cure gained significant traction, leading to health risks and public confusion. Similarly, in the United States, conspiracy theories about 5G technology causing COVID-19 resulted in vandalism of telecommunications infrastructure, as documented by Ahmed et al. (2020).

Despite widespread misinformation, certain mitigation strategies showed effectiveness. Collaborative efforts between governments and social media companies to flag or remove false information were reported to reduce the virality of some narratives (Nature, 2021). A case study on Facebook's partnership with fact-checking organizations demonstrated that labelling posts as misleading reduced their engagement rates by up to 80% (Aïmeur et al., 2023). However, these efforts often lagged behind the rapid spread of misinformation, highlighting the need for proactive measures.

Additionally, campaigns focusing on increasing health literacy emerged as pivotal. Studies by Paul Machete & Marita Turpin revealed that public awareness programs emphasizing critical thinking and source verification significantly reduced the likelihood of individuals sharing false information (Machete and Turpin, 2020). Similarly, tailored interventions targeting specific myths—such as WHO's "MythBusters" initiative—proved effective in debunking common misconceptions, particularly when culturally contextualized messages were employed. A study by Birunda et al. proposed Automatic COVID-19 misinformation detection (ACOVMD) in Twitter using a self-trained semi-supervised hybrid deep learning model. The experimental results show that the proposed model achieves 80.92% accuracy and 98.15% accuracy in the 10 and 80% label-seen experiments, respectively (Birunda et al., 2024). A study by Lu et al. embraced uncertainty features within the information environment. It introduced a novel Environmental Uncertainty Perception (EUP) framework for detecting misinformation and predicting its spread on social media, which showed that the EUP alone achieved notably good performance, with detection accuracy at 0.753 and prediction accuracy at 0.71. This study makes a significant contribution to the literature by recognizing uncertainty features within information environments as a crucial factor for improving misinformation detection and

spread-prediction algorithms during the pandemic (Lu et al., 2024). A study by Zhao et al. proposed a novel health misinformation detection model was which incorporated the central-level features (including topic features) and the peripheral-level features (including linguistic features, sentiment features, and user behavioral features). The model correctly detected about 85% of the health misinformation (Zhao et al., 2021).

Discussion

Infodemics spread and impact on public health

The COVID-19 infodemic, a term describing the rapid and widespread dissemination of misinformation and disinformation during the pandemic, is a complex issue influenced by societal, technological, and psychological factors (WHO, 2020a). While digital platforms played a pivotal role in amplifying misinformation, the effectiveness of interventions to mitigate its impact remains debatable. A critical analysis of the mechanisms driving misinformation spread, the limitations of current strategies, and areas requiring further research is necessary to formulate a more comprehensive response. The amplification of misinformation on digital platforms can be attributed to algorithmic biases that prioritize engagement over accuracy. Studies by Cinelli et al. (2020) and Vosoughi et al. (2018) suggest that emotionally charged misinformation spreads more rapidly than factual content (Cinelli et al., 2020; Vosoughi et al., 2018). However, these studies primarily focus on Western social media landscapes, raising concerns about their generalizability to regions with different digital ecosystems and media consumption patterns. Additionally, while social media platforms have introduced measures to curb misinformation, such as fact-checking partnerships, the effectiveness of these interventions is inconsistent.

Effectiveness of different mitigation strategies

While AI can rapidly identify disinformation campaigns, its reliance on pattern recognition increases the likelihood of false positives, particularly when distinguishing between satire and harmful misinformation (Pennycook and Rand, 2022). This contrasts with human fact-checking efforts, which, though slower, provide nuanced contextual understanding. The interplay between these approaches remains a contentious debate, with some scholars arguing for a hybrid model that combines AI efficiency with human oversight to balance speed and accuracy (Zhang et al., 2023). Others highlight the susceptibility of AI systems to adversarial manipulation, where misinformation creators adapt content to evade automated detection, raising concerns about long-term sustainability. Meanwhile, human fact-checking, despite its strengths in contextual analysis, faces challenges related to scalability and biases introduced by individual or institutional perspectives. The debate between AI-driven and human-led approaches underscores the need for a more integrated strategy that considers the strengths and weaknesses of both methodologies. For instance, Pennycook and Rand (2021) found that flagged misinformation was less likely to be shared, yet Guess et al. (2020) demonstrated that such efforts had minimal impact on users entrenched in misinformation echo chambers (Pennycook and Rand, 2021; Guess et al., 2020).

Additionally, fact-checking is not always effective in changing the beliefs of individuals deeply embedded in misinformation echo chambers. Echo chambers, where people are repeatedly exposed to like-minded opinions and selective information, reinforce pre-existing biases and make individuals resistant to correction, even when presented with credible evidence. Psychological factors play a key role in this resistance (WHO, 2020b). Confirmation bias leads people to seek, interpret, and remember information in ways that align with their existing beliefs while dismissing contradictory facts. The backfire effect can also occur, where direct confrontation with fact-checks strengthens rather than weakens false beliefs. Emotional investment in misinformation, particularly when linked to identity or ideology, further reinforces resistance to correction (Pennycook and Rand, 2022). Technological factors also contribute to this challenge. Social media algorithms prioritize engagement, often amplifying misleading content and reinforcing belief systems within closed networks. When fact-checks appear in such environments, they may be rejected outright or perceived as biased attacks, especially if they come from sources that individual's distrust. Research suggests that while fact-checking remains a valuable strategy, it must be combined with other approaches for greater impact. Media literacy programs can help people critically evaluate information before they form rigid beliefs. Narrative-based corrections, where misinformation is debunked through storytelling rather than direct contradiction, have shown promise in overcoming resistance. Encouraging open dialogue and trust-building within communities may also help reduce misinformation's grip (Kbaier et al., 2024; Cinelli et al., 2020). This contradiction suggests that fact-checking alone is insufficient, particularly when cognitive biases and ideological predispositions influence information consumption.

Another major intervention—trusted messengers—has shown promise in countering misinformation, yet its success is contingent on cultural and contextual factors. Research by MacKay et al. highlights the credibility of healthcare professionals and community leaders in disseminating accurate information (MacKay et al., 2022). However, the assumption that trust in these figures translates to behavioral change is problematic. A case study from India by Sundaram et al. demonstrated that community health workers effectively addressed vaccine hesitancy through direct engagement (Sundaram et al., 2023). Nevertheless, this approach may not be scalable in urban or digitally interconnected populations, where misinformation circulates rapidly and personal interactions are limited (Journal of Primary Care Specialties, 2021). Furthermore, there is insufficient research on whether trust in experts extends to digital platforms, where misinformation thrives.

Regulatory measures targeting digital platforms have also been proposed to curb the infodemic, yet their implementation remains contentious. Germany's NetzDG law mandates the removal of illegal content within 24 h, a model cited as effective in reducing hate speech (Library of Congress, 2021; Human Rights Watch, 2018a). However, concerns about censorship and freedom of expression complicate its adoption on a global scale. Furthermore, the lack of transparency in how platforms determine what constitutes misinformation raises ethical and practical dilemmas. A standardized, international

TABLE 3 Comparative table of different misinformation countermeasures, detailing their effectiveness and limitations.

Countermeasure	Evidence of effectiveness	Limitations
Fact-Checking	In a study done by Pennycook and Rand (2021) was found that accuracy prompts offer a promising strategy for reducing misinformation sharing online. This internal meta-analysis of 20 experiments (N = 26,863) conducted between 2017 and 2020 evaluates their reliability and generalizability. Results show that accuracy prompts enhance sharing discernment, primarily by reducing sharing intentions for false headlines by 10% (Vosoughi et al., 2018).	Limited impact in echo chambers where individuals resist corrections (Guess et al., 2020).
Digital Literacy Programs	A meta-analysis synthesizes 49 experimental studies (N = 81,155) assessing its efficacy. Findings indicate that media literacy interventions enhance misinformation resilience (d = 0.60), reducing belief in misinformation (d = 0.27), improving discernment (d = 0.76), and decreasing sharing (d = 1.04) (Huang et al., 2024).	Long-term effectiveness at scale remains uncertain; requires sustained engagement.
AI-Driven Content Moderation	A study with over 2,000 participants found that using ChatGPT (GPT-4 Turbo) to challenge conspiracy theories reduced belief in them by 20%, with 25% of participants shifting from above to below 50% confidence. On TikTok, flagging unsubstantiated videos decreased shares by 24% and likes by 7% (Hernandez et al., 2021), while Facebook's fact-checking labels reduced content views by up to 95%. AI moderation on Facebook removes nearly 100% of spam, 99.5% of terrorist content, 98.5% of fake accounts, 96% of adult content, and 86% of graphic violence (Komendantova and Erokhin, 2025).	Risk of false positives; struggles with nuanced content like satire or regional misinformation.
Trusted Messengers	A study examined how social validation, through trusted endorsements and bandwagon heuristics, influences misinformation credibility on Instagram. Experimental findings reveal that endorsements from reputable sources significantly increase perceived credibility of misleading content, highlighting the role of social cues in misinformation evaluation (Mena et al., 2020).	Limited scalability; effectiveness depends on cultural and contextual trust factors.
Regulatory Measures	A study analyzed Facebook posts and comments to assess potential overblocking and chilling effects of Germany's NetzDG law, which targets hate speech on social media. Examining 10 popular public pages, findings show no robust evidence of excessive content deletion, despite a slight increase in removed comments per post. Additionally, no significant change in user engagement or comment tonality was observed (Maaß et al., 2024).	Raises concerns about censorship and freedom of expression; enforcement varies by region.

approach to content moderation is necessary, yet the feasibility of such a framework remains uncertain given the divergent regulatory environments across countries (Trengove et al., 2022).

The contradiction between the effectiveness of digital literacy campaigns and the persistence of misinformation-related beliefs presents a critical challenge in misinformation research. Some studies advocate for digital literacy as a key intervention, arguing that training individuals to critically evaluate information sources reduces their susceptibility to false claims (Finland Toolbox, 2024). Programs like Finland's media education initiative have been highlighted as promising models that integrate critical thinking into curricula, fostering long-term resilience against misinformation. However, other studies suggest that belief persistence—where individuals cling to preexisting views despite corrective information—undermines the impact of such initiatives. Cognitive biases, such as the backfire effect and motivated reasoning, may lead people to reject or reinterpret corrective messages in ways that reinforce their existing beliefs. This discrepancy raises questions about whether digital literacy efforts can significantly alter misinformation consumption patterns or whether they merely benefit those already inclined toward critical engagement. Furthermore, there is a need to examine how digital literacy interventions interact with different sociocultural and psychological factors, as well as their scalability in diverse populations. Addressing these contradictions requires a more nuanced approach that accounts for cognitive resistance to factual corrections and the broader social dynamics of misinformation spread.

Furthermore, inconsistencies in research findings highlight the need for adaptive policy frameworks. Policymakers must consider variations in audience responses, the influence of social media algorithms, and the trustworthiness of fact-checking organizations when designing interventions. A rigid, one-size-fits-all approach may fail to address the complexity of misinformation spread. Instead, policies should be evidence-driven and flexible, incorporating ongoing research to refine strategies over time.

Artificial intelligence models have shown promise in identifying disinformation campaigns. However, their reliance on pattern recognition can lead to challenges, such as distinguishing between satire and harmful misinformation. For instance, a study revealed that existing fake news detectors are more likely to flag AI-generated content as false, while often misclassifying human-written fake news as genuine, indicating a bias in detection mechanisms (Ghiurău and Popescu, 2025). The advent of generative AI technologies has facilitated the creation of deepfakes—highly realistic but fabricated content—which poses significant threats to information integrity. These AI-generated media have been implicated in spreading false information across various domains, including politics and health, complicating efforts to maintain information accuracy (Sunil et al., 2025). Automated content moderation systems, while efficient, can inadvertently perpetuate biases present in their training data. This can lead to unjust outcomes, such as the disproportionate removal

TABLE 4 Summary of key themes in the infodemic and misinformation landscape.

Theme	key findings
1. The Role of Digital Platforms in Amplifying Misinformation	Digital platforms facilitate the rapid spread of misinformation through algorithm-driven content amplification, echo chambers, and virality mechanisms. Social media dynamics often prioritize engagement over accuracy, contributing to widespread misinformation.
2. Interventions to Combat the Infodemic	Effective strategies include fact-checking, debunking false claims, and promoting authoritative sources. Multi-stakeholder collaborations among governments, health organizations, and tech companies are critical in mitigating misinformation.
3. The Role of Trusted Messengers	Public figures, healthcare professionals, and community leaders play a crucial role in disseminating accurate information and countering misinformation. Trust in messengers significantly influences public perception and adherence to factual information.
4. Proactive Regulation of Digital Platforms	Regulatory frameworks aimed at increasing platform accountability, enforcing transparency in algorithms, and implementing content moderation policies are essential to controlling misinformation. Balancing free speech and regulation remains a key challenge.
5. Enhancing Health and Media Literacy	Improving public resilience to misinformation requires education on media literacy, critical thinking skills, and the ability to discern credible sources from unreliable ones. Health literacy initiatives empower individuals to make informed decisions.
6. Bridging the Digital Divide	Unequal access to digital resources contributes to misinformation vulnerability. Addressing disparities in internet access, digital literacy, and socioeconomic barriers is crucial for ensuring equitable access to reliable information.
7. Technological Innovations in Misinformation Management	AI-driven fact-checking, machine learning models for misinformation detection, and blockchain-based verification systems are emerging tools in managing digital misinformation. Continuous innovation is needed to keep up with evolving misinformation tactics.

of content from certain groups. Therefore, incorporating human oversight is crucial to mitigate these biases and ensure fair content moderation practices.

Despite the various strategies employed to combat the COVID-19 infodemic, significant gaps remain in understanding the psychological mechanisms that drive misinformation adoption and resistance to correction. Future research should prioritize comparative studies that examine the effectiveness of interventions across different sociocultural contexts. Additionally, longitudinal studies assessing the durability of fact-checking, media literacy programs, and regulatory measures would provide deeper insights into sustainable solutions. Regulatory measures targeting digital platforms have also been proposed to curb the infodemic, yet their implementation remains contentious. Germany's NetzDG law mandates the removal of illegal content within 24 h, a model cited as effective in reducing hate speech. However, concerns about censorship and freedom of expression complicate its adoption on a global scale.

Here is a comparative table (Table 3) of different misinformation countermeasures, detailing their effectiveness and limitations (Table 4).

Strategies to enhance resilience against infodemics in future health crisis

Recommendations for future research

To effectively address the challenges posed by infodemics, future research must focus on a multi-faceted approach that combines technological, behavioral, social, and policy-driven strategies (Rodrigues et al., 2024; WHO, 2020b; Briand et al., 2021). Given the complex nature of misinformation and its far-reaching consequences, particularly in times of crises like the COVID-19 pandemic, it is essential to identify and explore key areas of intervention. The following areas are crucial to the ongoing effort to combat misinformation, each addressing different dimensions of the issue:

Algorithm transparency

Research into algorithm transparency should aim at developing frameworks for ethical algorithm design. This could involve making algorithmic processes more understandable and accessible to the public, ensuring that platforms are held accountable for the content they promote. Platform-driven interventions, such as X's Community Notes and Facebook's misinformation labels, aim to curb misinformation through algorithmic adjustments and user-driven corrections (Tan, 2022; Yu et al., 2024; Dujeancourt and Garz, 2023).

Behavioural insights

Understanding the psychological factors behind the belief and sharing of misinformation is essential for designing interventions that target the root causes of these behaviors. Psychological theories of belief formation, cognitive biases, and social influence can provide crucial insights into why people are so easily influenced by misinformation. For instance, cognitive biases such as confirmation bias, where individuals seek out information that confirms their pre-existing beliefs, play a critical role in the spread of falsehoods. Emotional responses to misinformation, such as fear or anger, also contribute to its virality, as these emotions increase engagement with content (Pennycook and Rand, 2021; Munusamy et al., 2024).

Global collaboration

Misinformation is not bound by borders, and its effects are global. The widespread nature of misinformation, especially on platforms like Facebook, Twitter, and YouTube, means that disinformation can easily cross geographical, political, and cultural boundaries. As a result, tackling the infodemic requires global cooperation and coordination among researchers, policymakers, and technology companies. Future research should focus on fostering international partnerships to share data, research findings, and best practices in combating misinformation (Adams et al., 2023; Desai et al., 2022; New WHO Review Finds, 2022).

Community-based strategies

While global and national interventions are crucial, community-based strategies are also vital for combating misinformation, especially in regions with limited access to digital literacy resources. Misinformation spreads rapidly in local communities through word-of-mouth, local media, and interpersonal interactions. Therefore, it is essential to evaluate the efficacy of grassroots efforts in building trust and promoting accurate information within communities (Oxford Academic, 2022; Borges Do Nascimento et al., 2022; Stover et al., 2024).

Policy impact

Regulatory and policy measures have been among the most widely discussed approaches to tackling misinformation (Tan, 2022). However, the effectiveness of these measures remains a subject of debate. Some countries have implemented stringent laws aimed at curbing the spread of false information. For example, Singapore's Protection from Online Falsehoods and Manipulation Act (POFMA) empowers authorities to issue correction orders to platforms and individuals found spreading falsehoods. While such measures have been successful in curbing some forms of misinformation, they have also raised concerns about censorship and the suppression of dissenting voices (Human Rights Watch, 2018b; Protection from Online Falsehoods and Manipulation Act, 2021; Nannini et al., 2024).

However, the future research avenues discussed above may face feasibility challenges. Finally, by assessing strategies to enhance public resilience against misinformation, this research highlights the importance of digital literacy, institutional collaboration, and proactive policy frameworks. These findings provide a foundation for developing robust misinformation mitigation strategies applicable to future health crises, reinforcing the necessity of a multidisciplinary approach in addressing digital misinformation.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

SB: Writing – original draft, Writing – review & editing. AS: Writing – original draft, Writing – review & editing.

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The author(s) declare that Gen AI was used in the creation of this manuscript. Generative AI was used. The author(s) verify and take full responsibility for the use of generative AI in the preparation of this manuscript.

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Drivers of vaccine mis/disinformation in the media: from personal beliefs to cultural dimensions

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Introduction: The unabated spread of vaccine mis/disinformation poses a great challenge to the achievement of the SDG 3 and Universal Health Coverage (UHC) goals. This systematic review synthesizes the drivers of vaccine mis/disinformation in the media and how geography shapes these drivers through the lens of Hofstede's cultural dimensions theory.

Methods: A search was conducted in Scopus, Web of Science, and PubMed for studies between 2011 and 2024, arriving at a final sample of 27 studies. Emerging drivers of vaccine mis/disinformation identified were categorized into four levels-individual, message, platform, and societal levels with the individual-level (personal-related) drivers dominating the spread of vaccine mis/disinformation.

Results: Results reveal that though individual-level drivers such as being right-wing authoritarian, religious, or being an older male drive the spread of vaccine mis/disinformation on the demand side, message-level drivers including emotional framing and introduction of expert cues in messages also significantly drive the spread of vaccine mis/disinformation from the supply side. Further findings revealed that the prevalent cultural dimension in different climes played significant roles in the prevalence of drivers across certain geographies.

Discussion: The high-power distance culture of developed societies such as North America reflected the prevalence of the message-level driver given the mature and robust research and media ecosystem. Conversely, African and Asian societies which are tilted to the collectivism dimensions of Hofstede's dimensions theory showed a higher propensity for individual-level drivers, given that the social identity in a collectivist society shapes the behaviors of individuals. The study concluded that cultural theories predict the dominance of how vaccine mis/disinformation spreads in different geographies. Further findings revealed an overlapping complementary relationship between drivers. It was thus recommended that future reviews and studies should deeply explore these relationships and how they shape vaccine mis/disinformation discourse across geographies.

Systematic review registration: https://www.crd.york.ac.uk/PROSPERO/recorddashboard, CRD42024601978.

KEYWORDS

vaccine mis/disinformation drivers, vaccine hesitancy, cultural dimension, systematic review, media

Introduction

Vaccines are among the safest preventive medical interventions in human history, averting an estimated 3.5 to 5 million deaths annually, markedly improving global health outcomes (WHO, 2024). Despite this, immunization rates continue to decline in many regions of the world, partly driven by vaccine hesitancy- the delay or outright refusal of vaccines despite availability (WHO SAGE Working Group on Vaccine Hesitancy, 2014). This continuously undermines global public health and immunization efforts (WHO, 2019) at achieving universal health coverage and the sustainable development Goal 3 (SDG3) targets. Declining immunization uptake due to vaccine hesitancy has dire implications for global health, evidenced by the recent resurgences of Measles in developed regions of the world, with a global mortality of over 140,000 in 2018 alone (Carrieri et al., 2019; CDC, 2024).

A key contributor to vaccine hesitancy is the twin problem of vaccine misinformation and disinformation -the spread (intentionally and unintentionally) of false information about vaccines. Recent studies (Nwachukwu et al., 2024; Serge Andigema and Tania Cyrielle, 2024; Morejón- Llamas, 2023) have linked vaccine hesitancy to widespread mis/disinformation and conspiracy theories about vaccines. Although this circulation of falsehoods about vaccines, with its far-reaching consequences has always existed (Eddy et al., 2023; Eichman and Bichianu, 2024; Schwartz, 2012), the recent COVID-19 pandemic marked a new era, an all-time high of widespread circulation of misleading vaccine narratives and aggressive anti-vaccine messaging. This proliferation has led to a distorted understanding of immunization facts among the public, prompting public skepticism toward vaccines (Posetti and Bontcheva, 2020), a critical challenge that negatively influences public health decision-making.

Public health practitioners, policymakers as well as researchers have advanced varying interventions- including fact-checking and debunking mechanisms - to combat vaccine mis/disinformation. Although the deployment of these interventions and efforts have yielded significant positive results as recorded in literature (Whitehead et al., 2023; Schmid and Betsch, 2022; Xue et al., 2022), vaccine mis/disinformation continues to spread, necessitating the quest for impactful interventions to combat this spread (Schmid and Betsch, 2022). Understanding how these messages circulate, particularly the factors that motivate widespread circulation becomes crucial for designing effective interventions that directly respond to these drivers.

The propagation of vaccine mis/disinformation is prompted by different influences including- contextual, individual/group, and vaccine-specific across different parts of the world (World Health Organization SAGE Working Group, 2014). Studies have increasingly focused on a diverse range of drivers behind the spread of vaccine mis/disinformation- ranging from the quest for financial gain (Tokojima Machado et al., 2020), to the emotional triggers, low media literacy, religious beliefs, right-wing authoritarian attitudes, and affordances of social media platforms through echo chambers (Dunn et al., 2015; Lundy, 2023; Moran et al., 2022). Even though these studies have explored drivers individually across different contexts, with different study designs, and studying different vaccine types, they have mainly created a fragmented view of these drivers in literature. In the quest for an all-encompassing intervention that provides broad-level view across all vaccine types, media types, and contexts, it becomes critical to synthesize available evidence regarding the drivers of vaccine mis/information. In the same development, the complex interplay of these drivers and regional/cultural orientation using established cultural theories additionally remains underexplored. Our review, therefore, addresses this gap in literature by synthesizing the existing studies while also evaluating the global and geography-specific prominence of the drivers of vaccine mis/disinformation, guided by the lens of the cultural dimensions theory.

Existing reviews have also provided different focus in literature, with some focusing on the broad health misinformation landscape (Wang et al., 2019), others narrowly focusing on the COVID-19 pandemic and vaccines (Malik et al., 2023; Skafle et al., 2022), focusing on single media types (social media) and specific vaccines, limiting their relevance to the vaccine mis/disinformation discourse in general. While these research efforts exist, none has holistically analyzed vaccine mis/disinformation drivers across all vaccine types, media types, disaggregated by geographical contexts. Based on the foregoing, this review, following PRISMA guidelines, systematically synthesizes published studies (between 2011 and 2024) to examine drivers of vaccine mis/disinformation across traditional and digital media, while examining the cultural dimensions of these drivers across geographic contexts.

Literature review

Key concepts

Misinformation and disinformation are key concepts in this review that guide the extraction of relevant data. Whereas Misinformation and disinformation both point to the dissemination of false and/or inaccurate information to the public by different actors (Praveenkumar, 2024), there is a difference in the intent. Misinformation is oftentimes not deliberate, and hence not intended to deceive or achieve preconceived sinister goals, while disinformation refers to the deliberate creation, presentation dissemination of verifiably false information to deceive the public intentionally, cause public harm, or for economic gain (European Commission, 2018). Equally, a UNESCO report (Posetti and Bontcheva, 2020) has broadly defined disinformation as "content that is false and has potentially negative impacts" (P.1). Further, they aver that the goal of the person producing or sharing such inaccurate content differentiates disinformation from misinformation.

Despite these stated differences in the use of both terms, the distinction appears to be more plausible theoretically, because it is difficult to differentiate in practice (Wang et al., 2019). Similarly, it has been shown that there exists an issue of conceptual clarity and distinction among and between these terms (Broda and Strömbäck, 2024), hence some studies explore these terms and conduct a general analysis without making major distinctions among them (Skafle et al., 2022). The incumbent study is not aimed at establishing the different ways the terms have been studied distinctly rather, it adopts all-encompassing approach to view the subject matter. Consequently, our review categorizes both terms in the same block of information disorder while not differentiating between both concepts as the impact of false content is potentially the same, irrespective of the intentions (Posetti and Bontcheva, 2020). Whereas drivers of false vaccine content could be outcomes of misinformation or disinformation, our goal in this review is to provide a broad perspective about the dissemination of misinformation and disinformation, the agent, the message, and the interpreter (Wardle and Derakhshan, 2017).

Other key concepts we have used in this review include drivers, and media. 'Drivers' has been used in previous research (Wang et al., 2019) to refer to the facilitators of the spread of misinformation across the media. Drivers in this study would range from message content to

characteristics of individuals, to platform characteristics, that enable the diffusion of vaccine mis/disinformation in the media. The media includes studies about the social media and traditional media. Existing reviews have significantly focused on social media in health and vaccine mis/disinformation discourses (Malik et al., 2023; Skafle et al., 2022), however, the circulation of vaccine misinformation predates the widespread use of the social media. It is based on this that we have deemed it fit to include studies from both media types.

Theoretical underpinning

This review is anchored on Hofstede's (2011) cultural dimensions theory and Wardle and Derakhshan's (2017) framework of information disorder. The Cultural dimensions theory explains the relationship between culture and the behaviour of the members of that culture. It describes the "effects of culture on the values of its members and how these values relate to the behaviour of people who live within a culture" (Nickerson, 2023). The theory goes beyond the collective nature of culture to espousing the idea that this phenomenon is connected to different collectives called dimensions. Hofstede initially identified four dimensions in his seminal work, namely; individualism and collectivism, power distance, uncertainty avoidance, and masculinity and femininity. Two more dimensions emerged as products of validation studies- long-term or short-term orientation (see Hofstede and Bond, 1988); and Indulgence versus Restraint (see Hofstede et al., 2010). A critical objective of our review is to examine the interplay of vaccine mis/disinformation drivers across different cultures marked by geographies, hence the adoption of this theory. Through the lens of these dimensions, we analyze and advance reasons for geographical variations in the drivers of vaccine mis/disinformation, showing why some drivers are more dominant in some cultures than others. Although the studies that led to the theory examined national cultures as the units of analysis, our review takes a broader geographical standpoint at the continental level.

In their elements of information disorder, Wardle and Derakhshan provide a lens through which disinformation and misinformation -both are components of information disorder- can spread (see Figure 1). They provide three major elements- the agent, the message, and the interpreter- to explain how the process of creating, producing, and reproducing mis/disinformation works. The agent for our study is like the interpreter who disseminates the message, however, our focus is on the characteristics and motivations of these actors as developed by Wardle and Derakhshan (2017), which could be financial, political, social, and psychological. These motivations provide a framework to clearly conceptualize the human characteristics and motivations that drive vaccine mis/disinformation. The message element in the framework provides an avenue to examine the framing and construction of vaccine mis/disinformation content and how the message is shaped to induce a certain kind of reaction by the spreaders- agents and interpreters. The framework guides our view of the major factors that drive vaccine mis/disinformation.

The cultural dimensions theory enables us to interpret how geographical/cultural variations affect the spread of vaccine mis/disinformation in different contexts, explaining why certain drivers are more dominant in a context than others. The *agent-message-interpreter* model provides a narrower lens, focusing on how individuals (not national cultures) and message characteristics drive the spread of vaccine mis/disinformation.

Existing evidence

Vaccine mis/disinformation, as major contributors to vaccine hesitancy has long been a subject of discourse among scholars, policymakers, and public health workers alike, given its continued influence on immunization programs across the world, limiting the potentials of achieving the SDG3 goal of universal health coverage (UHC). While the WHO has noted that vaccine hesitancy is a continuum between acceptance and outright refusal of vaccines

FIGURE 1
Agent-message-interpreter framework of information disorder. Source: Wardle and Derakhshan (2017).

(WHO SAGE Working Group on Vaccine Hesitancy, 2014), the proliferation of vaccine mis/disinformation contribute to each phase of the hesitancy spectrum.

Reviews have explored issues around misinformation and disinformation in health with limited focus on vaccines in general. While some of these reviews have a narrow focus, if they are about vaccines, others treat broader issues around health misinformation. The closest review to the current study (Zhao et al., 2023), in our opinion focused on misinformation evidence related to COVID-19 vaccines alone, without geographical insights explained through the lenses of a cultural theory. The review synthesized evidence on the prevalence, features, influencing factors, impacts, and solutions as regards COVID-19 misinformation from January 2020 to August 2022. In the same vein, a similar study (Skafle et al., 2022) - a rapid review of COVID-19 misinformation on the social media was conducted in 2021, with strict focus on COVID-19 as a pandemic and disease, not a specific focus on vaccines. On one hand, these reviews were narrow in scope, given that they were limited to the COVID-19 pandemic or vaccines, leaving out evidence about studies that focused on other vaccines, while on the other hand they omitted studies that were published before 2020 and beyond 2022. It has been noted that the spread of vaccine misinformation did not commence with the COVID-19 vaccines (Eddy et al., 2023; Schwartz, 2012), and such, there is a critical need to explore earlier studies about other vaccines before the start of the COVID pandemic.

Another review (Malik et al., 2023) recently explored the factors related to the sharing of COVID-19 misinformation on social media. The researchers discovered five major factors associated with COVID-19 misinformation sharing on social media, including socio-demographic characteristics, financial considerations, political affiliation or interest, conspiracy ideation, and religious factors. This review provided a blueprint for creating categories from the drivers of misinformation in the media; however, the review was significantly targeted at the COVID-19 pandemic in general, with less emphasis on vaccines, which is the focus of the current study. While this review focused on the disease, it provides a concrete blueprint for separating drivers or factors into varying categories.

Other studies have researched the spread of health misinformation generally. A review (Moran et al., 2022) explored the drivers of health-related misinformation between 2012 and 2018. The review revealed how immunization and infectious diseases were prevalent in health misinformation discourses, with a significant number of studies from the social media. This study, however, paid little attention to the drivers of vaccine misinformation in the media.

Current literature about the drivers of mis/disinformation, illustrated by the identified systematic and rapid reviews, falls short of proffering solutions to the continued spread of vaccine mis/disinformation across the media. These studies have either generally focused on COVID-19 vaccines alone, focused on only social media, focused on shorter timeframes, focused on the broad health misinformation spectrum, or laid emphasis on the interventions advanced against the spread. This reveals a gap, which this current study fills by synthesizing evidence about all vaccines, with a geographical nuanced perspective, across both traditional and social media, and as well as an extended timeframe which stretches from the decade of vaccines (World Health Organization, 2019) to the aftermath of the COVID-19 pandemic. This is with the aim of providing a single, concise evidence.

Methods

We conducted a systematic literature review of peer-reviewed published articles on three major public health databases- Web of Science (WoS), Scopus, and PubMed to retrieve relevant articles following PRISMA guidelines. The research team unanimously developed and agreed on a protocol and search strategy for the review, pre-registered on Prospero with reference number CRD42024601978.

Database search

Our team searched the databases in September 2024 to retrieve relevant articles for the study. These databases have been employed in a range of previous reviews encompassing vaccination misinformation (Skafle et al., 2022; Zhao et al., 2023). The search included articles published in 14 years (01/01/2011 to 30/06/2024) at the intersection of vaccines, mis/disinformation, media, and drivers. The study period was decided upon to ensure that our review covers a crucial period in global immunization that witnessed an increased relevance of the new media in health communication dynamics (Huo and Turner, 2019; Putri et al., 2023; Yao, 2024). This period witnessed a surge in vaccine discourses with 2010–2020 being labeled as the decade of vaccines (World Health Organization, 2019). Studies related to the pandemic, the Ebola epidemic, as well as the development and adoption of a wide range of vaccines in different countries are targeted. The researchers also retrospectively extended the timeframe to be able to ascertain trends beyond the immediate COVID-19 pandemic, which resulted in an *infodemic* as cautioned by the WHO Director General (WHO, 2020). Search languages were limited to English language and Spanish since the research team has a combination of proficiency in both languages.

Search strategy

Studies were included regardless of their methodological quality and risk of bias. The focus on describing and synthesizing patterns rather than establishing causation influenced the decision to include studies despite their Risk of Bias. Our searches included MeSH terms as well as keywords and synonyms relevant to the study objectives which bother on the media, vaccines, drivers (or influencers), as well as mis/disinformation. The search keywords/terms were generated from previous similar studies as well as from initial pilot searches conducted by the study team members (Table 1).

The study included original observational and intervention studies published in peer-reviewed journals. Other inclusion criteria were:

i Articles with a focus on vaccination (all types of vaccines) and dis-misinformation spread.
ii Studies that have any objective(s) that deal with drivers (implicitly or explicitly) of vaccine mis/disinformation.
iii Articles written in English or Spanish languages.
iv Studies from all fields of knowledge. Not limited to health or communication sectors.

TABLE 1 Search strategy.

Search theme	Keywords used	Boolean operators	Combined search string
Driver	Driver*, factor*, cause*, influencer*, determinant*, *facilitator*	OR	Driver* OR factor* OR cause* OR influencer* OR determinant* OR *facilitator*
Vaccines	Vaccin*, immuni*	OR	Vaccin* OR immuni*
Mis/ disinformation	Misinformation, "fake news", disinformation, "false information"	OR	Misinformation OR "fake news" OR disinformation OR "false information"
Media platform	Media, "mass media", "social media", Facebook, Twitter, Instagram, TikTok, YouTube, radio, newspaper, television	OR	Media OR "mass media" OR "social media" OR Facebook OR Twitter OR Instagram OR TikTok OR YouTube OR radio OR newspaper OR television
Final string		**AND**	**Combine the above using 'AND'**

Bolded terms indicate the finalsearch string, which is a combination of all the keywords using the 'and' boolean operator for database queries.

Our strategy excluded review articles of all types as well as opinion papers, position, conceptual, or argumentative papers without original empirical evidence, book chapters, theses, clinical trials, conference papers, reports, letters, editorials, comments, and textbooks. We also excluded studies with no objective focused on drivers of dis/misinformation in the media or those that were not related to vaccine misinformation, disinformation, fake news, or conspiracy theories. All the authors agreed on the inclusion and exclusion criteria applied in the studies and two actively participated in the entire article selection process.

First, searches were conducted on individual strings concerning the four major components of the study (vaccine, media, mis/disinformation, and drivers). After these four initial searches were conducted using the ''or'' Boolean operator and the ''*'' truncator operator, a fifth search combining these four initial searches using the ''and'' Boolean operator was conducted to arrive at the results.

Data screening and extraction

Generated search results from the different databases were exported in Zotero-compatible file types for further reference management. We used Zotero reference management software to process the generated results and automatically detect duplicates. A researcher conducted abstract and title screening by applying the stated eligibility criteria to identify potentially relevant studies with active guidance from a second researcher. The full texts of these potentially eligible articles were retrieved and initially reviewed by one of the research team members. This was followed by another phase where this was discussed by a second team member, going over any potential concerns to arrive at full consensus. A plan was in place to resolve any emerging disagreements over the eligibility of studies through discussion with the third team member (see Figure 2).

Synthesis and analysis

The included articles were inductively coded using Microsoft Excel data management and cleaning software. These codes were eventually categorized into different themes based on the level of society to provide a manageable list for discussion of drivers of vaccine misinformation in the media. The major categories for this theme were the drivers, while other categories focused on geography of study, methods employed, the media analyzed, as well as types of vaccines studied.

Data was extracted from the objectives, methods, results, and discussion sections of included studies. The Microsoft Excel data management application was used to organize, systematize, and code studies. Table 2 shows a summary of extracted data grouped according to study, relevant objective, study method, country/continent, media/population group analyzed, sample size, vaccine studied, and conclusion. Qualitative narrative synthesis was employed to discuss the key findings and results. After data extraction, summaries in the form of narrative answers were developed with the review objectives in mind. Qualitative narrative synthesis has been used in previous studies (Catalán-Matamoros et al., 2019) and has proven to provide an effective means of producing an actionable knowledge base to inform further policy and practice (Denyer and Tranfield, 2006).

Results

The search included 27 studies which were fully analyzed, with data inductively extracted using an Excel-based code sheet.

General description of the study sample (analyzed studies)

Our sample reveals an almost stable trend in the number of studies from 2011 with a significant dramatic upward shift in publication from 2022. The majority of the studies ($n = 24$) were after the pandemic started in 2020, while three were conducted before the COVID-19 (see Table 2, Figure 3).

Types of media studied

The most studied mass medium is the social media ($n = 18$). No study analyzed strategies or drivers employed in traditional media, including their online versions, which suggests that the traditional media has minimum to no contribution to the diffusion of vaccine mis/disinformation. The most analyzed social media platform in exploring the drivers of mis/disinformation in our sample was Twitter

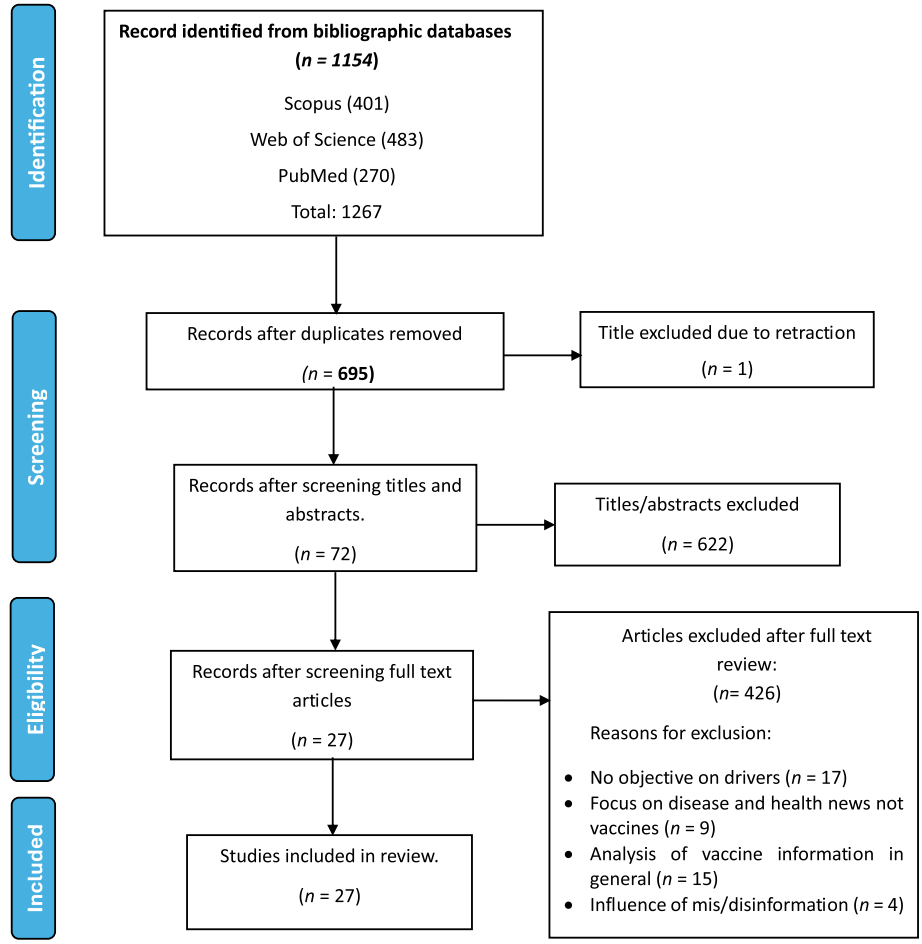

FIGURE 2
Prisma flow diagram.

(now X) ($n = 12$) out of the 18. Other social media platforms studied were Instagram ($n = 3$), TikTok ($n = 1$), YouTube ($n = 1$), and Facebook ($n = 1$). A study (Okuhara et al., 2018) analyzed the contents of Japanese anti-vax campaigners´ websites. No study in our sample analyzed content from multiple social media platforms.

Geographies studied

In the total sample, roughly 75% ($n = 18$) were linked to a country or geographic region, while three articles (Hoffman et al., 2019; Schulte-Cloos and Anghel, 2024; Unfried and Priebe, 2024) out of these focused on more than one country. These three included a survey (Unfried and Priebe, 2024) conducted among participants from six African countries- Ghana, Kenya, Nigeria, South Africa, Tanzania, and Uganda. From Europe, Schulte-Cloos and Anghel (2024) conducted an online experiment with participants from Hungary and Romania, while Hoffman et al. (2019) analyzed localized American Facebook content that included data contributions from the US and eight other unnamed countries. Other countries studied included the US ($n = 6$), while a few other countries appeared once – Iran, France, China, Jordan, Japan, Bangladesh, Finland, Brazil, and Spain.

At the continental level, North America was studied most ($n = 7$). Other continents studied included Europe ($n = 4$), Asia ($n = 5$), South America ($n = 1$), and Africa ($n = 1$).

Figure 4 illustrates an uneven distribution of studies across continents, pointing to the dominating power of individual countries in regional/continental discourse. For example, the North American data is dominated by the US, leading to ass regional perspective shaped by US-originated research orientation, media system, methods, as well as politics. In contrast, even though only one study was included from Africa - (Unfried and Priebe, 2024) - five countries were represented, underscoring the value of multi-country studies in presenting representative insights from one region. This further offers a broader policy and cultural context, serving as an example of how to amplify underrepresented voices.

Methodological characteristics of included studies

Most of the studies ($n = 19$) adopted content analysis as the major design while other studies employed surveys ($n = 3$), and quasi-experiments ($n = 5$). We categorized modeling and linguistic analysis, as well as analyses of websites as content analytical studies seeing that

TABLE 2 (Continued) Characteristics of selected studies

Study	Design	Continent/ Country	Relevant objective	Platform/ population group	Sample size	Vaccine studied	Conclusion
Unlu et al. (2024)	Content analysis	Europe- Finland	To investigate the stance on COVID-19 vaccines and the spread of misinformation on Twitter in Finland	Twitter	1,683,700 tweets	Covid-19 vaccine	The emergence of highly interconnected misinformation and anti-vaccine networks towards the pandemic's latter stages poses significant challenges for public health communication. This polarisation reveals that simply providing facts is insufficient to counter misinformation
Unfried and Priebe (2024)	Online survey	Africa- Ghana, Kenya, Nigeria, South Africa, Tanzania, and Uganda	To estimate the magnitude and determinants of deliberate and accidental sharing of misinformation related to three vaccines (HPV, polio, and COVID-19).	Humans (>17 year old from 6 countries)	5307 respondents	HPV, Polio, and Covid vaccines	Deliberate sharing of vaccine misinformation content is related to being older and risk-loving, accidental sharing is associated with being older, male, and high levels of trust in institutions. The results shed light on the detection and sharing of health misinformation in a realistic online setting, providing novel insights on who is susceptible to fall for and more likely to disseminate fake news
Tokojima Machado et al. (2020)	Content analysis- case study	South America- Brazil	To understand how M&D about vaccines circulate on YouTube in Portuguese	YouTube	52 videos containing Mis/ disinformation about vaccines	Not mentioned	The study concluded that vaccine-related misinformation and disinformation on YouTube in Portuguese is driven by themes that exploit public fears, economic incentives for content creators, and distrust in traditional institutions, with YouTube's recommendation algorithm potentially amplifying the reach of this harmful content.
Sharevski et al. (2022)	Experiment	Not mentioned	To analyse how Twitter users engage with tweets containing both valid information and misleading information about COVID-19 vaccines	Humans (>18 twitter users)	606 participants	Covid-19 vaccine	One's hesitancy to person- ally receiving a vaccine or administering them to children sees the rumours more "accurate" and had more of an appetite to engage with them on Twitter, confirming the past evidence on engagement with misinformation.

Study	Design	Continent/ Country	Relevant objective	Platform/ population group	Sample size	Vaccine studied	Conclusion
Schulte-Cloos and Anghel (2024)	Experiment	Europe-Hungary and Romania	To investigate how specific contextual factors related to information processing on social media contribute to the spread of vaccine-related fake news	Humans	2848 (1414 Romania, 1434 Hungary)	Covid-19 vaccine	The fast and intuition-reliant nature of decision-making on social media encourages the spread of misinformation that is in line with individuals' ideological beliefs, which could increase social polarisation in societies.
Samya et al. (2023)	Quasi-Experiment	Asia-Bangladesh	To investigate the factors that contribute to the propagation of COVID-19 vaccine misinformation on social media in Bangladesh	Humans (university-level students)	202 participants	Covid-19 vaccine	Trust in the source of information, especially when it involves personal connections, is a significant factor in the rapid sharing of COVID-19 vaccine misinformation on social media in Bangladesh. This trust leads people to share news hastily without verifying its accuracy
Saini et al. (2022)	Content analysis	North America-US	To examine the associations between the characteristics of vaccine stance tweets and the likelihood and number of retweets	Twitter	150,388 English tweets from US	Covid-19 vaccine	The dissemination of antivaccine messages is associated with both content-related and content-unrelated characteristics. Because antivaccine tweets with positive emotions, objective content, and concrete words are more likely to be disseminated, policymakers should pay attention to antivaccine messages with such characteristics
Pierri et al. (2023)	Content analysis	Not mentioned	To investigate the patterns of prevalence and contagion of COVID-19 vaccine misinformation on Twitter	Twitter	294,081,599 tweets shared by 19,581,249 unique users	Covid-19 vaccine	The wide spread of misinformation around COVID-19 vaccines on Twitter during 2021 shows that there was an audience for this type of content. Our findings are also consistent with the hypothesis that superspreaders are driven by financial incentives that allow them to profit from health misinformation

Study	Design	Continent/ Country	Relevant objective	Platform/ population group	Sample size	Vaccine studied	Conclusion
Okuhara et al. (2018)	Content analysis: websites	Asia- Japan	To explore beliefs underlying the messages of anti-influenza vaccination websites	Antivaccine websites	113 websites	Influenza vaccine	Website authors may engage in anti-vaccination activities because they want to feel they are virtuous, saving people from harm caused by vaccination, and to boost their self-esteem, thinking "I am enlightening uninformed people."
Moran et al. (2024)	Content analysis-digital ethnographic approach	Not mentioned	To examine the role of social media influencers and the parasocial relationships they build with audiences in the spread of vaccine -opposed messaging and how this information is leveraged for profit	Instagram	Purposive sample of three Instagram "wellness" or "alt. health" influencers for over four months	Covid-19 vaccine	The monetisation routes and the normalisation of content sharing for profit afford misinformation sharers numerous ways to financially benefit from the spread of vaccine misinformation, presented as everyday wellness advice
Moran et al. (2022)	Content analysis-thematic analysis	Not mentioned	To analyse how vaccine-opposed users on Instagram share anti-vaccine content despite facing growing moderation attempts by the platform	Instagram	14 days worth of content from 137 accounts of antivaccine promoters	Covid-19 vaccine	Despite visible attempts at content moderation and changes to policy, anti-vaccination messaging is still prevalent on Instagram. Problematic communities, like those sharing anti-vaccination messaging, cultivate tactics to share and amplify vaccine-opposed messaging despite active moderation attempts.
Mønsted and Lehmann (2022)	Content analysis	Not mentioned	To ascertain the analyses on the interplay between strong vaccination stances, social network structure, and online information	Twitter	60 billion tweets	Covid-19 vaccine	Vaccine discourse is highly polarised, with pro- and anti-vaccine users forming distinct, tightly-knit communities, or "epistemic echo chambers," that amplify specific beliefs and diminish exposure to opposing viewpoints.

Study	Design	Continent/ Country	Relevant objective	Platform/ population group	Sample size	Vaccine studied	Conclusion
Miri et al. (2024)	Quasi-Experiment	Asia- Iran	To investigate the impact of message framing (emotional vs rational) on social media users' ability to accurately detect information and their intention to share messages about the COVID-19 vaccine	Humans (adults)	600 participants	Covid-19 vaccine	While emotional appeals can be an effective tool in health communication, their use needs to be carefully managed, particularly in contexts like vaccine information, where the potential for spreading misinformation is high.
Manuel Noguera-Vivo et al. (2023)	Content analysis	Europe- Spain	To find out if the type of Twitter account influences the behaviour of the disinformation flows of the anti-vaccine discourse	Twitter	36292 tweets	Covid-19 vaccine	Typology of the accounts can be a predictive factor about the behaviour of users who spread disinformation
Lundy (2023)	Content analysis	Not mentioned	To find out how vaccine misinformation spreads on the platform despite the platform's actions to combat misinformation	TikTok videos	100 videos	Covid-19 vaccine	Misinformation spreads in complicated and difficult-to-track ways on microvideo platforms. TikTok's novel reusable audio and interaction features create new avenues for misinformation spread
Lu and Xiao (2024)	Survey	Asia- China	To understand the process of how exposure to COVID-19 information on social media could result in misinformation sharing through individuals' heuristic processing of information.	Humans (18 to 70 year old internet users)	1488 respondents	Covid-19 vaccine	While a low level of trust strengthened the association between exposure to COVID-19 vaccine information on social media and the affect heuristics, a high level of trust strengthened its association with the availability heuristics, both of which were associated with misinformation sharing.
Hoffman et al. (2019)	Content analysis	North America- US and 8 other unmentioned countries	To characterise the spread of antivaccine content on Facebook	Facebook (antivaccine commenter accounts)	197 accounts	Not mentioned	Those opposed to vaccination often misrepresent data and skew risk perception when spreading their messages on Facebook, suggesting that media literacy or entertainment narratives may be effective avenues for intervention

Study	Design	Continent/ Country	Relevant objective	Platform/ population group	Sample size	Vaccine studied	Conclusion
Harris et al. (2024)	Content analysis	Not mentioned	To characterise role of perceived experts acting as potential antivaccine influencers online	Twitter	4.2 million posts	Covid-19 vaccine	Perceived experts are not only some of the most effective voices speaking out against vaccine misinformation; they may be some of its most persuasive sources.
Faccin et al. (2022)	Content analysis (modelling)	Europe- France	To assess how vaccine-critical contents gained ground during the pandemic	Twitter	3m tweets	Covid-19 vaccine	Vaccine-critical activity does not strictly follow the media agenda that in its turn is more strictly connected to the evolution of the pandemic. The share of vaccine-critical contents in these debates remains stable except for a limited number of short periods associated with specific events
Dunn et al. (2015)	Content analysis (machine learning)	Not mentioned	To measure whether exposure to negative opinions about human papillomavirus (HPV) vaccines in Twitter communities is associated with the subsequent expression of negative opinions	Twitter	83,551 tweets; 957,865 social connections among 30,621 users	HPV vaccine	Twitter users who were more often exposed to negative opinions about the safety and value of HPV vaccines were more likely to tweet negative opinions than users who were more often exposed to neutral or positive information
Di Domenico et al. (2022)	Mixed/multi method (coded as survey for study III)	North America - US	To explore the processes through which health misinformation from online marketplaces is legitimised and spread	Humans (US Amazon consumers)	399 participants	Not mentioned	Expert cues drive social media sharing behaviour through legitimacy.
Daradkeh (2022)	Content analysis (Machine learning and Modelling)	Asia- Jordan	To scrutinise topics and sentiments surrounding misinformation about the COVID-19 vaccine on social media	Twitter	40,359 tweets	Covid-19 vaccine	Misinformation with negative sentiment is more likely to be re-posted and shared than misinformation with positive sentiment, with high audience engagement and interaction.

Study	Design	Continent/ Country	Relevant objective	Platform/ population group	Sample size	Vaccine studied	Conclusion
Calac et al. (2022)	Content analysis	North America - US	To assess the spread of misinformation linked to erroneous claims about Hank Aaron's death on Twitter	Twitter	436 tweets	Covid-19 vaccine	Misinformation targeted at minority groups and echoed by other verified Twitter users has the potential to generate unwarranted vaccine hesitancy at the expense of people such as Hank Aaron who sought to promote public health and community immunity.
Baker and Walsh (2023)	Content analysis	North America-US	To examine how the maternal is appealed to, and represented, by anti-vaccine advocates online during the pandemic	Instagram (anti-vaccination dozens' +1 accounts)	9 month worth of content from 8 of the 13 accounts	Covid-19 vaccine	Maternal is strategically invoked in anti-vaccine content by appealing to three interrelated ideal types: the protective mother; the intuitive mother and the doting mother. These portrayals of the maternal are used to encourage vaccine refusal by presenting hegemonic ideals
Argyris et al. (2022)	Content analysis (Machine learning)	Not mentioned	To identify sets of linguistic features that facilitate and inhibit the propagation of vaccine-related content	Twitter	51360 tweets	Not mentioned	Anti-vaccine tweets use quotes more than pro-vaccine tweets, which have significant and positive impact on both retweets and favourites. Anti-vaxxers quote other sources presumably in their attempt to make their content credible and objective
Alieva et al. (2023)	Content analysis	North America-US	To ascertain the strategies used to spread Covid-19 vaccine disinformation stories throughout Pennsylvania	Twitter	6 million tweets	Covid-19 vaccine	Negative messaging often attracts people's attention and encourages them to share it. Anti-vaccination users employ positive network and narrative manoeuvres to promote vaccine hesitancy and anti-vaccination beliefs on Twitter in southwestern Pennsylvania.
Ali et al. (2022)	Quasi-experiment	North America-US	To elucidate the effect of certain cognitive heuristics on the perceived credibility and sharing motivations of fake anti-vaccination news on social media.	Humans (>18 US residents)	813 participants	Not mentioned	The findings reveal consistent evidence that fear motivates anti-vaccine individuals to believe in and share fake news, while anger motivates people who are neutral towards vaccines to do so.

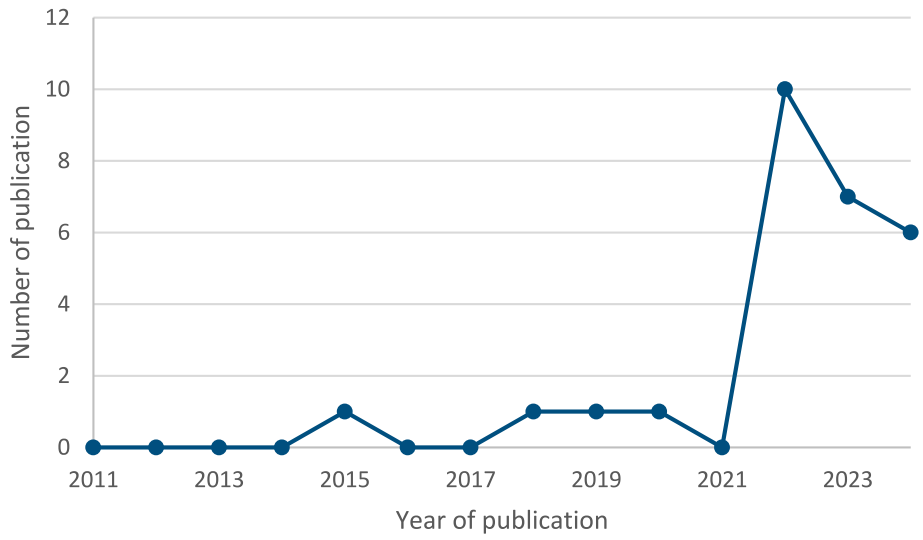

FIGURE 3
Trend in studies conducted by year of publication.

their basic strategy was generating manifest content from social media and/or websites. The content analysis focused significantly on using advanced machine-learning techniques to ascertain the drivers of misinformation in the media. Studies monitored social media content and their diffusion patterns significantly by engagement metrics (comments, shares, tweets, retweets, likes) while also exploring the range of the spread of posted vaccine mis/disinformation messages. It was not stated if the posts in this category were texts or images or videos, however, two studies analyzed video content- one on YouTube (Tokojima Machado et al., 2020), and the other on TikTok (Lundy, 2023). The sample sizes in the selected articles varied according to the research designs adopted. The majority of the content analytical studies analyzed posts ranging from 436 tweets to 6 billion tweets. The studies that analyzed videos had smaller samples- 100 videos on TikTok, and 52 videos on YouTube. The other studies with humans as subjects of study (surveys and experiments) had samples ranging from 202 to 5,307 human participants.

Type of vaccine studied

COVID-19 vaccines ($n = 19$) dominated the discourse, supporting the earlier finding that most of the studies were conducted after the advent of the COVID-19 pandemic. Other vaccines studied included the influenza ($n = 1$) and the HPV ($n = 1$) vaccines. A significant proportion of our sample (5 studies, 19%) did not specify particular vaccines. One study (Unfried and Priebe, 2024) focused on more than one vaccine- HPV, Polio, and COVID-19 vaccines.

Drivers of mis/disinformation in the media

Our sample presented a wide array of drivers and motivators of vaccine mis/disinformation in the media. Our findings show a list of 34 emerging drivers coded from the respective studies. The emerging drivers were categorized into four distinct levels of drivers for reference. Our taxonomy is based on the emerging factors discovered from the review. These broad drivers include individual-level drivers, message-level drivers, network/platform-level drivers, and structural-level drivers.

We have defined these levels of drivers as:

a Message-level drivers- The motivators and appeals in the development and crafting of media content that make for easy spread and dissemination of vaccine mis/disinformation in the media.
b Individual-level drivers- These are factors related to personal characteristics (cognitive, demographic, and psychographic) that render individuals liable to disseminate vaccine mis/disinformation in the media.
c Platform-level drivers- These drivers are about the characteristics of the media platforms that allow for and are manipulated to spread vaccine mis/disinformation.
d Structural and societal-level drivers- These are related to broader society and contextual factors that drive vaccine mis/disinformation in the media.

The majority ($n = 17$) of the studies showed multiple drivers (more than one driver) while the rest ($n = 10$) had a single driver. We hence coded the occurrence of each driver as single cases under the categories adopted for the review as listed above. We coded a total of 63 cases/observations for the categories. Individual-level drivers had the most cases ($n = 26$). Occurrences of other categories were message-level drivers ($n = 16$), platform-level drivers ($n = 14$), and structural and societal-level drivers ($n = 7$). This reveals a dominance of individual-level considerations in the spread of vaccine mis/misinformation in the media. Interestingly, even though more content analytical studies typically focus on message-level factors, the individual-level drivers dominated the discourse, suggesting a broad tendency to interpret message content through individual psychology lens (see Supplementary material 1 for full list of specific drivers).

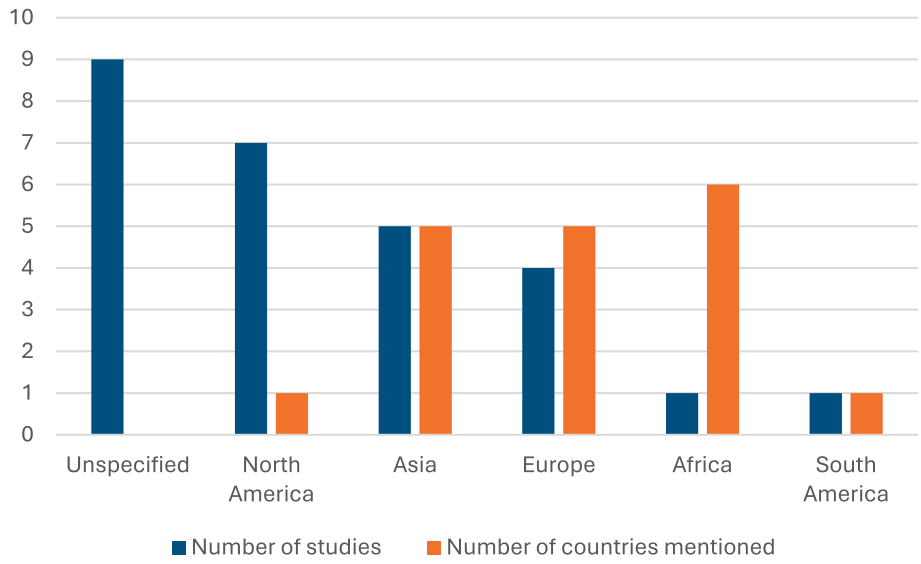

FIGURE 4
Studies distribution by geography.

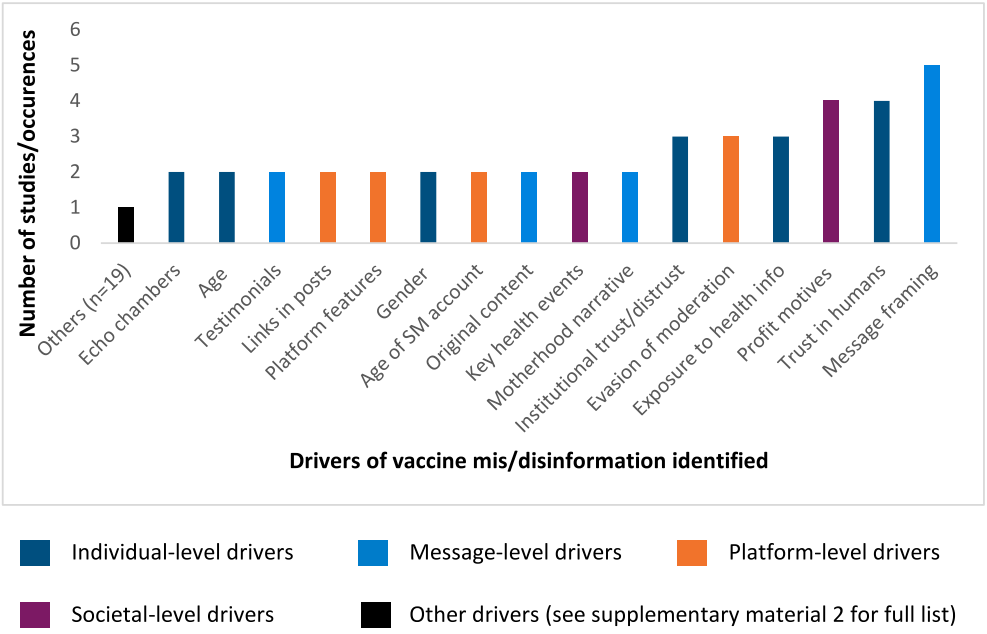

FIGURE 5
Identified drivers observed across studies (n = 63) according to driver categories (see Supplementary material 1 for full classification).

Figure 5 presents observations for specific drivers across the reviewed studies. The *message-framing narrative*, which discussed the linguistic components of vaccine mis/disinformation content was coded in more studies others (n = 5). These frames included the use of concrete words (Saini et al., 2022); negative emotions and maneuvers (Unlu et al., 2024). Further, *trust in sources* (n = 4) and *profit motives* (n = 4) followed closely. The findings align with results about the methods adopted, where content analysis, typically a message-centered design dominated. The regular citation of trust in sources also points to the continued focus on individuals who would share vaccine mis/disinformation messages if they trust a source, as against the accuracy of the message especially if the source is an expert (Di Domenico et al., 2022; Harris et al., 2024), or if they are personally connected to the source with the source (Samya et al., 2023). The quest for gain also drove vaccine mis/disinformation across the media, showing that "super spreaders driven by financial incentives that allow them to profit from misinformation" (Pierri et al., 2023). The data also highlight a long list of less-frequently cited drivers that appeared only once or twice, underscoring the need for further empirical observation to capture dynamics that are not widely

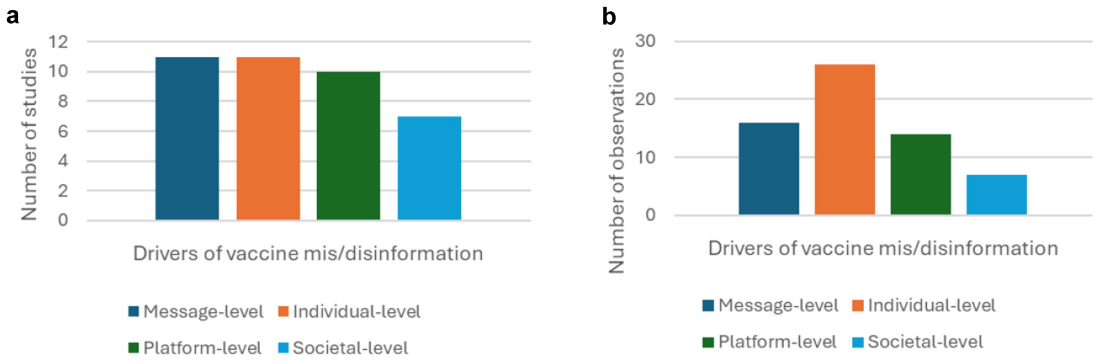

FIGURE 6
(a) Number of studies across driver categories. **(b)** Number of observations across driver categories.

represented in literature (see Supplementary material 2 for full list of drivers across categories).

Data in Figures 6a,b show complementary insights into broader vaccine mis/disinformation driver-levels regarding the studies that discovered at least one driver in a category (Figure 6a) and the frequency of observation (Figure 6b) across the dataset. The data implies that although categories could be identified by equal number of studies, it does not necessarily imply its dominance or depth in literature. For instance, the case of message-level and individual-level drivers. This suggests that individual-level drivers (such as trust, age, beliefs) may be significantly influential in driving vaccine mis/disinformation and should therefore be a key focus for designing interventions.

Drivers according to geographies studied

In responding to objective 2, we sought to ascertain the emerging drivers from the different geographies studied. 18 out of the articles included in our review mentioned a focal country, hence our analysis is based on these 18 studies. This analysis was based on the continents represented, rather than individual countries since countries in the same continents most often share similar characteristics that make them amenable to similar experiences and interventions. The continents identified from the studies included Africa, Asia, Europe, North America, and South America. It should be noted that the US was the only country in our sample that was from North America, while Brazil was the only country from South America. Two –North America and Europe- of these five continents had drivers spread across all 4 categories/levels of drivers (Figures 7a,b).

Figure 7a illustrates the disparity in thematic diversity in the drivers of vaccine mis/disinformation across continents. Europe and North America stood out as the most thematically diverse geographies with all four driver categories- individual, message, platform, and societal- represented in their findings. This suggests a developed research capacity as well as greater engagement and understanding of the complexity of the mis/disinformation ecosystem in these regions. This wide representation may also be influenced by the volume of studies, seeing that these two geographies were among the most represented in our sample.

In contrast, Figure 7b shows a more continent-specific picture of driver categories. For example, individual-level drivers drive majority of vaccine mis/disinformation in Asia and Africa, pointing to a more human-centered interpretation of vaccine mis/disinformation drivers. Further aligning with cultural frameworks such as Hofstede's cultural dimensions theory, which links these regions with collectivist inclinations, a dimension which might have affected how mis/disinformation spreads and how researchers from these geographies explore this pattern. The dominance of message-level drivers in North America further points not only to a developed media ecosystem but could have also been shaped by the design of many of the studies from the region (e.g., content analysis). The limited presence of platform and societal-level drivers in Asia and Africa further suggests an under-exploration of deeper network factors in these contexts, showing a research orientation that might be prioritizing individual behaviors over institutional or technological issues (see Supplementary material 3).

In Europe ($n = 4$), all the levels of drivers were evident in the sampled studies. Antivaccination promoters in Europe made use of significant events in the development of a health event- The COVID-19 pandemic in this case to drive vaccine misinformation. Faccin et al. (2022) discovered that the antivaccination crusaders used the announcement of the Pfizer vaccine, the documentary- hold-up-, AstraZeneca retraction in Denmark, and health pass in Europe to drive vaccine mis/information spread across the media. In Finland, vaccination mis/disinformation spreads in the media through deliberate attacks on pro-vaccine authorities by responding to posts by these authorities (Unlu et al., 2024), further revealing a low power-distance dimension where hierarchies and authorities can be questioned. This in turn amplifies their messages as followers of these pro-vaccine government agencies. The age of social media accounts (older accounts) (Manuel Noguera-Vivo et al., 2023), and possession of right-wing authoritarian attitudes by users of social media (Schulte-Cloos and Anghel, 2024) also promote the dissemination of vaccine/misinformation across the media in Europe.

North American studies explored different drivers of vaccine mis/disinformation cutting across all the four levels of drivers. For example, misinformation posts that were not flagged and labeled as vaccine misinformation (Calac et al., 2022) had the propensity of being shared across social media (platform-level driver). Profit goals were not exactly part of the drivers of vaccine mis/disinformation in North

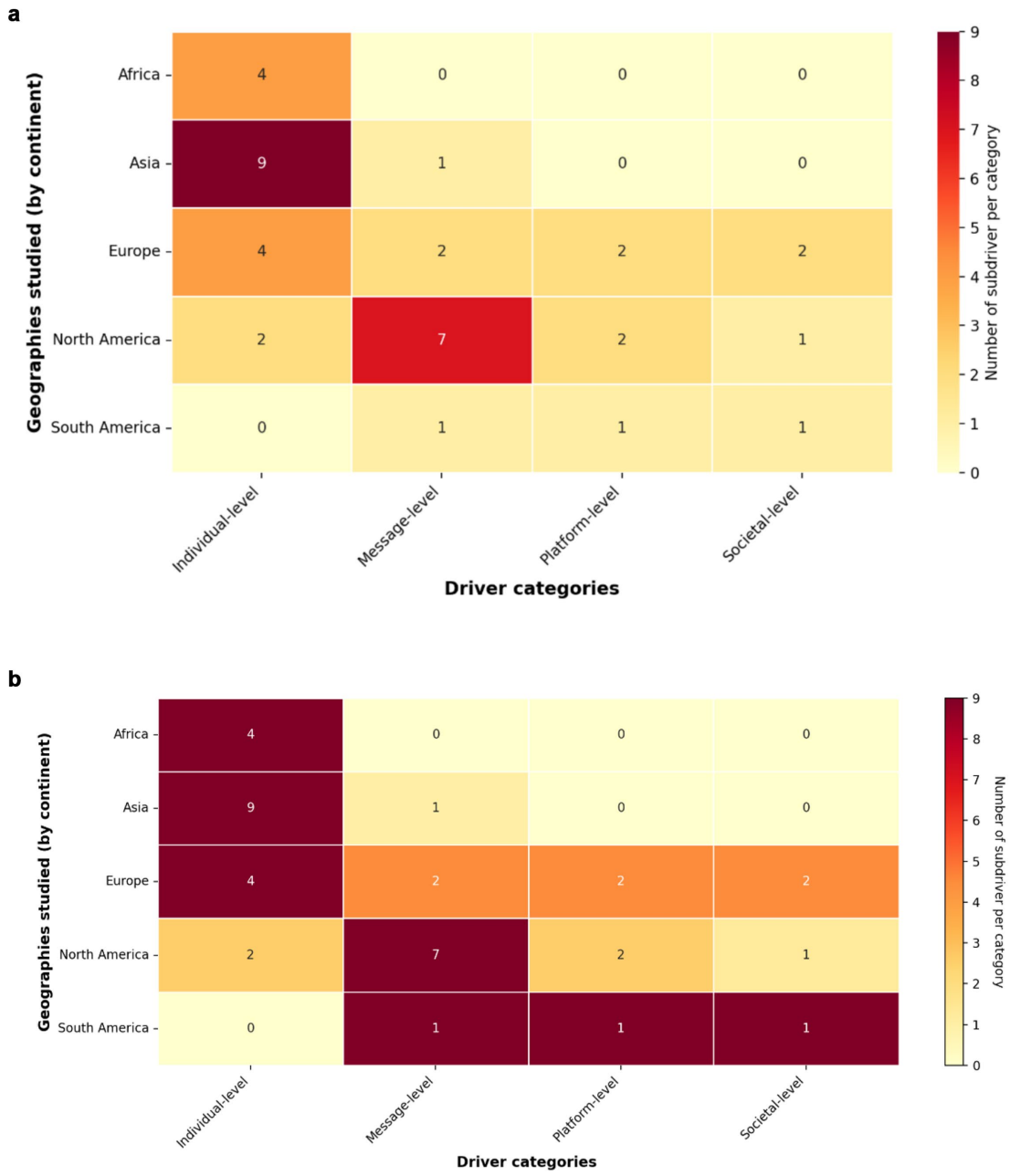

FIGURE 7
(a) Heatmap showing the number of specific drivers reported under each driver category across continents. **(b)** Heatmap displaying the relative intensity of driver categories within each continent. Color intensity is normalized by row. Colors show relative intensity within each geography (row). Numbers show actual values.

America, however, message-level factors such as appeal to motherhood emotions (Baker and Walsh, 2023) were used to generate profit through alternative healthcare promotion. Perceived expert cues via medical qualifications (individual-level driver) would increase the propensity of a vaccine mis/disinformation post being shared by North Americans (Di Domenico et al., 2022). Objective content, and concrete words (Saini et al., 2022) also proved to be a major determinant of vaccine mis/disinformation spread in North America. The event of the death of a major baseball player (Hank Aaron) after taking the COVID-19 vaccine also shaped the spread of vaccine mis/disinformation in the media as (Calac et al., 2022) discovered.

Discussion

We sought to synthesize existing evidence around the spread and diffusion of vaccine mis/disinformation in the media. Our review is specifically aimed at identifying the potential drivers of vaccine mis/disinformation across the media, exploring the geographies that have been studied for this, and how the different drivers relate to the different geographical landscapes studied. This was to explore existing gaps in the literature and provide actionable insights that will serve as a springboard for future research efforts and interventions to counter vaccine misinformation in the media. 27 studies published between 1

January 2011 and 30 June 2024 were included based on our criteria after a series of processes as shown in Figure 2.

Preliminary findings show a geometric increase in studies conducted during and after the COVID-19 pandemic, further confirming that the COVID-19 pandemic heralded a new era of mis/disinformation's popularity in vaccine discourse in literature. Our analysis reveals that the majority of the studies analyzed social media platforms, which confirms the tenets of Veblen and McLuhan's technological determinism theory (Madaki et al., 2024; Marshall, 1962) that the available technology of an era drives all its civilization, including health communication scholarship. The social media continues to be a major driving force in the spread of vaccine mis/disinformation, making it the most studied media type further justifying the focus of earlier reviews on misinformation (Wang et al., 2019; Skafle et al., 2022) on social media alone. The absence of studies focusing on the traditional media points to this fact.

Drivers of vaccine mis/disinformation in the media

The factors that drive vaccine mis/disinformation in the media were categorized into distinct levels. Individual-level drivers emerged as the most frequently identified motivators of vaccine mis/disinformation in our sample, followed by message-level drivers with the other two –platform and societal levels- appearing less frequently. The findings point to the centrality of individual factors in the spread of vaccine mis/disinformation in the media. These drivers included mistrust in institutions (Hoffman et al., 2019), existing biases in health beliefs (Sharevski et al., 2022), conservative right-wing authoritarian attitudes (Schulte-Cloos and Anghel, 2024), avoidance of cognitive dissonance with mental fatigue of platform users (Mønsted and Lehmann, 2022), and trust in expert sources (Samya et al., 2023). Studies have continuously demonstrated how skepticism and existing biases toward government institutions, and pro-vaccination actors fuel the spread of health mis/disinformation (Jaiswal et al., 2020; Lee et al., 2024). Trust in the source of mis/disinformation holds great potential for a user to disseminate such misinformation without paying cognitive attention to the veracity of the details of such messages since it does not demand too many resources from the decision-maker (Unlu et al., 2024; Siegrist, 2021). Even though a majority of the studies adopted content analysis as research design, which is naturally disposed to message-level analysis, the dominance of individual level occurrence points to the centrality of the agent and interpreter in the information disorder ecosystem as seen in Wardle and Derakhshan (2017).

On the other hand, message-level drivers such as emotional and negative framing of messages accompanied with different emotions, and testimonials from 'past witnesses' also strongly promote the spread of vaccine mis/disinformation in the media. The dominance of the message, agent, and interpreter components in the propagation of vaccine mis/disinformation aligns with the general postulation of the *agent-message-interpreter* framework of information disorders. Previous reviews have discovered the dominance of these factors in the spread of misinformation in other similar areas- health (Wang et al., 2019), COVID-19 (Malik et al., 2023), COVID-19 vaccines (Skafle et al., 2022), further showing a similar trend in vaccine-focused studies and the relevance of the interrelatedness of these drivers in the mis/disinformation discourse.

Although the other categories- platform-level and societal level drivers- were found with less frequency, their occurrence reveal a larger challenge with current interventions, the inability of existing automated debunking mechanisms in stopping the spread of all vaccine mis/disinformation (Schmid and Betsch, 2022; Sun and Ma, 2023; Zhang et al., 2021).

The dataset also provides insights into the sustained relevance of individual-level drivers such as mental as well as its interplay with message-level drivers. While both drivers were identified and cited in equal number of studies (10 each), individual drivers emerged with a higher frequency of observations, suggesting not only wider distribution but also greater relevance and depth in vaccine mis/disinformation discourse. Conversely, message-level drivers such as message framing, appeal to emotions, use of scientific sources, use of concrete and vivid expressions, etc., though appearing in multiple studies, were less frequently observed, suggesting a possibility of an interplay between the two highest ranking drivers. This further implies the possibility of the message-level drivers serving as avenues to infer deeper individual-level motivations since the individual reacts to the content based on their own beliefs as it aligns with certain content in the message. Overall, this position reinforces the critical role the individual –agent and interpreter- in the vaccine mis/disinformation discourse.

Drivers and geography studied

Geographical (and by extension, cultural) peculiarities affect the spread of vaccine mis/disinformation across the media. Factors including the development of the media and social media system, economic development, and media literacy level, which vary widely across different geographies impact the spread of misinformation. When examined at a continental level, the drivers of vaccine misinformation slightly vary, giving nuanced insights that can be leveraged in designing tailor-made interventions for different cultural and/or regional contexts. Continents share similar characteristics in cultural and media consumption patterns, as well as economic and literacy levels. This approach prioritizes the significant role of localized responses in a global crisis that thrives on regional peculiarities. Existing literature buttresses the adoption of public health interventions that are culturally relevant to maximize impact (Grover et al., 2024; Pope et al., 2024; Pastrana et al., 2020).

The prominence of the US in geographies studied aligns with the fact that misinformation has largely been popularized from the US, especially since the 2016 presidential elections (Gaultney et al., 2022; Padda, 2020). Studies from Europe and Asia also ranked quite high in the vaccine misinformation drivers literature, corroborating the prevalence of mis/disinformation in developed Western cultures (Skafle et al., 2022; Li et al., 2023). Africa and South America – two of the world's least developed continents- were the least researched, in line with a recent review (Skafle et al., 2022). The low output from less-developed regions portends a risk-filled future for these societies, seeing that they might be more susceptible to misinformation due to low media literacy. Low immunization uptake, which is correlated to misinformation is highest in least developed societies (World Bank, 2021) where antivaccination campaigners may likely exploit the

ignorance of the populace to drive their cause. This further amplifies the recent calls for more health communication research from low-income societies, given that they account for only 0.27% of global health communication research output (Mheidly and Fares, 2020).

In a broad sense, the review reveals the dominance of individual-level drivers across all continents represented except one- South America, underscoring the significance of personal factors – particularly trust in institutions and sources, age and gender- in driving the spread of vaccine misinformation across different cultural contexts. While cultural contexts might differ, these shared psychological factors are universal. The absence of individual-level drivers in the South American study (Tokojima Machado et al., 2020) could be significantly due to the nature of the study- YouTube videos from anti-vaxxers were analyzed.

Throughout our sample, Europe and North America had the most varied drivers of vaccine misinformation in the media. They both had all four level drivers of vaccine misinformation identified, though granular factors slightly differ. Misinformation, particularly health misinformation has long been associated with more developed countries/continents in the global North (Li et al., 2023), hence the identification of all categories of drivers in these contexts. However, in North America –dominated by the US- message-level drivers are more eminent, implying the level of sophistication in the research ecosystem regarding the availability and application of technological tools for natural language processing (Getzoff, 2023), as well as a developed media ecosystem. The developed status means there is relative freedom of expression, and freedom after expression, unlike less-developed countries. This freedom enables citizens and dwellers alike to propagate what they deem fit on social media, which may be vaccine mis/disinformation, aligning with what Jeremy Bentham recognizes as 'the liberty of doing mischief' (Phiri, 2023). This liberty is part of what Hofstede refers to as power distance in his cultural dimensions theory, where the US ranks low (Hofstede, 2011).

In Africa, only individual-level drivers were identified. Though only one study was in our sample, data was collected from six African countries. The prevalence of individual-level drivers such as age, gender, and trust in Africa shows how deep-rooted social beliefs play a role in driving vaccine misinformation. Older males in Africa are more prone to sharing vaccine misinformation in the media. This finding aligns with existing literature that older people are less media literate, and are more inclined to share conspiratorial conjectures given their deeply rooted socio-cultural beliefs (Akello, 2024; Osuagwu et al., 2023), owing to widespread poor media literacy and a paucity of media literacy interventions in the continent (Boshoff and Fafowora, 2024; Cunliffe-Jones et al., 2021).

Similarly, the Asian context, dominated by individual-level drivers, reflects similar regional and cultural characteristics with Africa. While the study designs, experiments, survey, and content analysis are different from that of Africa- survey-, the result reflects deeper dimensions of similarity and focus on individuals as major contributors to the spread of vaccine/disinformation in the media. Asia and Africa's emphasis on individual-level drivers such as age and gender are traceable to established theories such as the cultural dimensions where group roles (collectivism) define and shape the way individuals act on vaccine mis/disinformation. Individual behaviors in these societies are thus deeply rooted in social expectations. Further, the recurrence of trust and mistrust in authorities, an outworking of high-power distance cultures in the cultural dimensions theory could be indicative of the collectivist tendencies in these cultures. Given that individual behaviors are shaped by collective expectations, it becomes easier for these groups to easily convince members to trust or mistrust authorities by spreading vaccine mis/disinformation. These dimensions therefore explain why individual-level drivers are prevalent in collectivist cultures.

There is a complex connection between message-level, platform-level, and structural/societal-level drivers in South America, particularly Brazilian antivaccination YouTube (Tokojima Machado et al., 2020). The use of links to external social media drives followers to these other platforms where they are fed with mis/disinformation and also get alternative health solutions sold. The antivaccination channel owners also use these platforms to collect testimonials from followers and feed them back into the YouTube channel, which amplifies the spread.

The complex mix of drivers from South America is reflective of the prevailing collective culture in the continent, seeing that Brazil ranks low on individualism in the cultural dimensions theory. In this type of culture, the basis of trust is relationship, which includes testimonials from past users of alternative health products, making the use of WhatsApp and Telegram groups veritable tools for community-driven dissemination of mis/disinformation. Interestingly, the socio-economic dynamics that tend to drive the spread of vaccine mis/disinformation reveal how such low-income settings –where legitimate income streams are not sufficient- propel the development of other avenues such as monetizing mis/disinformation for livelihood.

Study limitations

Our review, despite following standard systematic review and evidence synthesis protocols, fell short in some respects, which might have affected the quality of the results. First, we did not include grey literature, conference papers, and pre-prints in this review. This might have limited the options of available evidence to synthesize, hence possibly leaving out some interesting insights that would have enriched the results. Second, the review was limited to articles in English and Spanish, leaving out studies in other languages, which might have affected the results generated. As a result of this exclusion, certain drivers or regions-specific mis/disinformation patterns might have been underrepresented in this review, leading to an incomplete understanding of what is known about the drivers of vaccine misinformation globally and regionally. While we acknowledge this limitation, research has established that the exclusion of non-English articles has little to no effect on systematic review results (Nussbaumer-Streit et al., 2020).

Furthermore, only three databases –WOS, Scopus, and PubMed- were searched to generate the analyzed studies based on available timelines and interests. While the combination of these three databases produces robust enough results, some relevant studies might have been inadvertently omitted from the review. Additionally, our review, particularly the analysis of drivers according to geographies, was skewed toward broad-level factors to provide an overview, thus limiting deeper-level insights that could have been generated from comparing individual-level factors and how they exactly drive vaccine mis/disinformation in different contexts.

Notwithstanding the foregoing limitations, this review has strengths in advancing evidence around the spread of vaccine mis/disinformation with study duration and data spanning years before the COVID-19 pandemic, evaluating how these drivers of mis/

disinformation spread vary and are shaped by different contextual realities based on geography.

Conclusion

Our review shows how drivers of vaccine mis/disinformation are not only thematically diverse, but also shaped by distinct cultural and socioeconomic dynamics across various regions of the world. While individual-level drivers are prominent across most of the continents studied, they were more prominent in regions with collectivist and high power-distance tendencies like Asia and Africa, where individuals' propensity to spread disinformation is largely shaped by group identity. Conversely, the dominance of message-level drivers in North America shows low power distance, and robust research ecosystem that supports complex analysis of content. These regional variations reiterate the need for tailoring interventions to combat vaccine mis/disinformation that go beyond what is being said or shared, but to the how, where, and within which cultural frame the circulation happens.

Future research directions

The findings from our review open up avenues for further exploration in critical areas that would foster better understanding around the spread of vaccine mis/disinformation.

Theoretically, future research could undertake an in-depth exploration of the interplay between cultural theories such as Hofstede's dimensions and the spread of vaccine mis/disinformation. Our review has applied the Cultural dimensions theory to explain broad-level differences across geographies; future empirical studies should go beyond category-level analyses to test the direction and strength of cultural characteristics in strengthening the prominence of specific drivers across geographies, with their theoretical implications. In addition, empirical studies could mainstream cultural theories in a narrower geographic classification than ours, since our review also did a broad-level classification of geographies to provide an overview based on continents. The theoretical implications of cultural theories would provide further insights necessary for explaining why specific drivers influence the spread and perception of vaccine mis/disinformation in specific geographies.

In terms of geographic context, there is a need for an equitable distribution of research outputs from the global south- particularly Africa, parts of Asia, and South America. Studies from less-developed continents –such as Africa and South America- remain scarce, omitting critical insights from these contexts, which contribute a significant quota to the global human population, and by extension, vaccine mis/disinformation spread. Despite the fact that the survey from Africa provides insights from six countries, it is not sufficient, as the interpretation or the design of the study could be influenced by the research orientation of the researchers. Limited representation from these parts of the world portends a form of looming challenge in global health, given that they contribute a significant percentage of low vaccine uptake. This status makes these societies even more relevant in providing empirical evidence. The lack of studies from these regions shows the increasing divide between the global north and south in terms of knowledge production. Interventions designed on data generated in other climes will be less potent in combating the challenges on the ground in these continents. Hence, there is an urgent need to conduct studies that not only focus on drivers, but also interventions from these regions.

Future studies from a constructs perspective, should undertake a deep dive into how specific drivers that are present in different geographies affect the spread of vaccine mis/disinformation in their respective cultures. For instance, if age drives vaccine misinformation in Africa and Asia for instance, how age drives misinformation in Africa could be largely different from how it does in Asia. It could be that the younger population are more susceptible in Asia, compared to Africa where the older population may be susceptible, showing deeper dynamics that can foster interventions that propel positive change.

Furthermore, our review highlighted the regional distribution of broad vaccine misinformation drivers with little focus on the overlapping nature of these drivers. The finding that message-level drivers could be a lens to eventually infer a connection with individual-level drivers needs further attention. The interconnected and mutually reinforcing nature of these drivers needs to be explored. For instance, how message-level appeals are amplified by platform-level drivers and individual dispositions. The interplay of these relationships in different geographical contexts could present insights that would lead to practical interventions for each society studied. In the same vein, the direction of influence of each specific factor ought to be explored.

From a methodological standpoint, as observed in previous reviews (Whitehead et al., 2023; Skafle et al., 2022; Zhao et al., 2023), the study of health misinformation has largely been conducted using textual and content analysis to identify patterns of spread in the media, with the majority using Twitter data. While this has been because the Twitter API lends itself to research-friendly ends, it is important to note that more insights from other social media platforms would be interesting to compare results between platforms, particularly multimedia-based platforms such as TikTok and YouTube. These platforms have become more popular among the younger population, and if vaccine mis/disinformation must be combated at all levels, a worthy next step would be generating empirical insights from these platforms. The continued dominance of short video content (from YouTube and TikTok) among fact-checked mis/disinformation content points to the urgent need to further explore these platforms (International Fact-Checking Network, 2025). Additionally, more insights need to be generated from locally dominant social media platforms such as the *WeChat* and *Weibo* in China.

In the future, ethnographic studies in mis/disinformation-prominent settings that focus on locally motivated drivers of vaccine mis/disinformation, particularly in low-income settings should be a major consideration. This would provide insights beyond self-reported surveys, content analysis, and social or quasi-experiments that have dominated the literature. The ethnographic studies should take a deeper dive into the individual-level drivers identified and explore the connection between cultures and these drivers based on careful observation. Insights generated from these studies, with definitions from the cultural dimensions theory, could provide an avenue where tailored intervention can be designed for specific societies with similar dominant cultural dimensions.

By addressing these gaps in theory, context, construct, and method, future studies can generate evidence that can inform practical interventions that would help combat the spread of vaccine mid/disinformation.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

OA: Conceptualization, Methodology, Project administration, Resources, Writing – original draft. DC-M: Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing – review & editing. CE: Methodology, Project administration, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that Gen AI was used in the creation of this manuscript. The authors declare that the JuliuAI (https://julius.ai/) data analysis tool was used to generate the heatmaps in Figure 7 after inputting data from the review. The AI support was solely data visualisation.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcomm.2025.1550216/full#supplementary-material

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Examining conspiracy theory spillover in the health communication arena: factors that impact COVID-19 conspiratorial beliefs and health-related behaviors

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This study examined the strength of different groups of individual-level variables in predicting conspiracy beliefs about Coronavirus disease (COVID-19) and related health behaviors by conducting a survey on a national online sample of U.S. adults. The results indicated that, among a wide range of individual-level variables, including psychopathological variables, cognitive variables, trust perceptions, trait emotions, health-related variables, and demographics, general belief in conspiracy theories (CTs) best predicted belief in specific COVID-19 CTs. In addition, our results showed that a stronger belief in COVID-19 CTs served as a significant predictor of engaging in less avoidance behavior. Furthermore, our results indicated that belief in general CTs does not directly lead to a change in avoidance behavior; the relationship is instead mediated by belief in COVID-19 CTs. Perceived severity of COVID-19 was the best predictor for proactive health behavior, whereas actual vaccination behavior was best predicted by confidence in COVID-19 vaccines. These results were interpreted using a framework that combines health communication theories with the concepts of path dependency and spillover effects in conspiratorial thinking.

KEYWORDS

conspiracy theories, COVID-19, health behaviors, spillover effect, public health

Introduction

In recent years, the rapid spread of conspiracy theories (CTs) via digital media platforms has affected communication in many countries worldwide and captured both public and scholarly attention. Researchers, politicians, and journalists have warned that conspiratorial narratives, or beliefs that ultimate causes of events are secret plots by powerful people or organizations (e.g., Coady, 2006), have overtaken online (Wood and Douglas, 2015), popular (Brotherton and French, 2014), political (Oliver and Wood, 2014) and scientific and medical discourses (Goertzel, 2010). In the medical arena, the percentage of Americans accepting CTs has been alarmingly high. For example, Oliver and Wood (2014) published that 37% of Americans thought that the U.S. Food and Drug Administration (FDA) refused to release the cure for cancer, and that only 46% disagreed that fluoridation was a secret plot to poison people. In 2020, Pew Research Center found, through a nationally representative panel of randomly selected U.S. adults, that a quarter of the surveyed U.S. adults believed that there

was at least some truth in CTs that powerful people intentionally planned the coronavirus outbreak (Schaeffer, 2020).

Researchers have warned that the spread of CTs could have potential detrimental effects (Hellinger, 2019; Oliver and Wood, 2014; Sunstein and Vermeule, 2009). Generally providing explanations for large-scale catastrophic events and containing generic content suggesting the suppression of information by governments, corporations, and scientists (Brotherton et al., 2013), conspiratorial narratives could play a major part in affecting individuals' attitudes, intentions, and behaviors. They have been shown to delay preventative care, decrease the willingness to vaccinate against potentially deadly diseases (Cheruvu et al., 2017; Mills et al., 2005), decrease trust and health-seeking intentions (Natoli and Marques, 2021), and increase general feelings of powerlessness, disillusionment, and mistrust in authorities (Jolley and Douglas, 2014). Those who endorse medical CTs were also found to be more likely to report using alternative medicines and avoiding traditional medicines and less likely to have annual check-ups or get influenza vaccinations (Oliver and Wood, 2014). This shows that conspiratorial narratives can have significant consequences in shaping long-term health-related behaviors and risk-taking, especially because unverified narratives tend to linger in memory and are hard to correct (Pluviano et al., 2017; Pluviano et al., 2020).

Therefore, it is crucial to further explore the role of conspiratorial beliefs in health-related behaviors during a pandemic such as Coronavirus disease (COVID-19), focusing on their impact on decreased health-related behaviors and the mechanisms through which these beliefs originate. So far research has found that different types of variables can impact beliefs in misinformation: cognitive variables (e.g., Pennycook et al., 2020), including trust (e.g., van der Linden et al., 2021), psychopathological variables (e.g., de Zavala et al., 2020; Hughes and Machan, 2021), conspiratorial variables (e.g., Dyrendal et al., 2021), media-related variables (e.g., Lukito, 2020), health-related variables (e.g., Jolley and Douglas, 2014), emotional variables (e.g., Tomljenovic et al., 2020), and demographics (e.g., Vijaykumar et al., 2021). Despite these commendable efforts, less research has investigated how these factors function together in predicting beliefs in COVID-19 CTs, as well as their impact on health outcomes.

To address this gap, our study first examined the strength of different types of individual-level variables in predicting conspiracy beliefs about COVID-19 and related health behaviors. It also evaluated the role of beliefs in CTs about COVID-19 in mediating the relationship between its strongest individual-level predictor and COVID-19 health-related behaviors. Identifying the strongest predictors of COVID-19 conspiracy beliefs and related health behaviors allows us to distinguish among the potency of influence of cognitive, emotional, and psychopathological factors on the human propensity to explain the world using dogmatic epistemologies reflective of conspiratorial thinking. The present study helps integrate currently fragmented literature, examining different aspects of conspiratorial variables in different contexts by providing a comprehensive lens on individuals' psychological and behavioral responses to pandemic information. Finally, understanding the role of CTs during pandemics will help public health organizations design more practical measures and policies to more effectively manage public health information communication that is increasingly impacted by users' behaviors in online environments.

Medical conspiracy theories and COVID-19

Conspiracy theories (CTs) assume that "a powerful network of actors works in secret against the public good" (Natoli and Marques, 2021, p. 902). Research has shown that medical CTs have been widespread throughout human history. The rhetoric of conspiracy was already prominent in Ancient Greece and Rome (Roisman, 2006), as well as elsewhere in the world, even among ancient tribes (Chagnon, 1968; Evans-Pritchard, 1963; Von Rueden and Van Vugt, 2015), indicating their universal nature and deep psychological bases. In American public opinion, conspiracy themes have been persistent for more than a century (Uscinski and Parent, 2014). Although not always wrong (e.g., Watergate Affair, War in Iraq), CTs are worrisome when their underlying thought principle becomes the dominant, if not the sole, explanation for a variety of social, political, economic, and health outcomes.

In the medical arena, CTs about vaccines have been particularly prominent. The discovery of the smallpox vaccine triggered rumors that it would cause people to grow horns, while the DTP vaccine allegedly caused convulsions and cerebral damage (Dyer, 1988). In a study later refuted, Andrew Wakefield claimed in 1998 that the MMR vaccines were linked to autism, triggering a new wave of moral panic against vaccinations (Goldacre, 2008). In Pakistan, the belief that the polio vaccine was designed by the CIA to make Muslim men sterile is still prevalent, making this country one of the few where polio disease has not been eradicated (Andrade and Hussain, 2018). CTs about viruses such as AIDS and Ebola, both of which are often interpreted as inventions by the U.S. government to reduce populations, have also been widespread (Bogart and Bird, 2003; Knight, 2013). The U.S. government has also been blamed for the crack cocaine epidemic across the United States in the 1980s, with allegations that it specifically targeted African Americans to keep them addicted while profiting from the illegal trade to finance paramilitary groups in Nicaragua (Webb, 2019). Big pharmaceutical companies have often been targets of CTs, suggesting that they have been withholding cures for deadly diseases such as cancer to make a profit or control the population (Ernst, 2019). Another narrative suggested that 'big pharma' and medical doctors lie about the effectiveness of treatments for depression, suppress alternative natural cures, and overprescribe antidepressants for financial gain (Goertzel, 2010; Oliver and Wood, 2014). The fact that some companies have indeed engaged in concealing serious side effects of their products (e.g., Lipitor lawsuits against Pfizer; see Dye, 2014) and the fact that extraordinarily high prices of medication did indeed make some individuals rich (e.g., as the lifesaving EpiPen price rose by 400%, the salary of the CEO was increased to an astonishing $18 million; Popken, 2016) only put oil on the fire.

The COVID-19 pandemic proved to be a fertile ground for various CTs that spread through social media faster than the respiratory virus, affecting millions of people around the globe. CTs, including that the COVID-19 virus was created by the "deep state" in an effort to spread panic or by the Chinese government to harm the U.S. economy, ran rampant in the early days of the pandemic (Motta et al., 2020). In May of 2020, a 26-min video entitled "Plandemic" went viral and was viewed more than 8 million times across social media platforms (Frenkel et al., 2020). The video, which originally circulated on a QAnon Facebook group, claimed that the virus and a future potential vaccine were created by powerful people for profit and power (Frenkel

et al., 2020). These conspiracies were adopted by a significant portion of the population. A survey of U.S. adult citizens conducted by the Pew Research Center found that while only 10% of Americans had watched "Plandemic," 71% had heard of the CTs spread in the video, and 25% of respondents said they believed the theory (Mitchell et al., 2020).

COVID-19 conspiracy theorists have also focused their attention on questioning the safety and efficacy of a vaccine, and they began spreading misinformation about it even before it was ready and available to the general public. One study found that 25% of respondents who answered their survey believed that the pandemic was being used as an excuse to "force a dangerous and unnecessary vaccine on Americans," and 20% believed that it was an excuse for someone to install tracking devices into their bodies (Enders et al., 2020, p. 5). The study encompassed a nationwide online survey of U.S. adults, whose demographic data aligned with U.S. Census demographic data. A poll conducted by YouGov also found that 20% of Americans believed the government was using the COVID-19 vaccine to microchip the population, and 83% of respondents who reported that they would not take the vaccine also reported belief in the theory that the dangers of COVID-19 were exaggerated for political reasons (Frankovic, 2021). A survey of almost 5,000 U.K. residents found that a smaller number endorsed a similar theory; only 8% of respondents believed that Bill Gates wanted to vaccinate people in order to implant microchips in them (University of Bristol and King's College London, 2021). However, the same survey also found that 14% of respondents believed a vaccine was only being developed to make money for pharmaceutical companies, while 13% did not know if that conspiracy was true or false (University of Bristol and King's College London, 2021). Those who endorsed any conspiratorial belief about COVID-19 were also significantly less likely to say they would receive a vaccine if and when it became available (University of Bristol and King's College London, 2021).

Other prominent COVID-19 CTs include the debunked claim that the Centers for Disease Control and Prevention (CDC) was exaggerating the death count from the virus (Rouan, 2021) and the false theory that 5G wireless networks accelerated the spread of the virus (Ahmed et al., 2020). In the early months of the pandemic, a video that circulated online featured a prominent doctor known for her extreme views and anti-vaccination beliefs who claimed that the CDC was encouraging medical examiners to report COVID-19 as the cause of death even when patients had underlying conditions (Dickson, 2020). Several months later, the CT was perpetuated in a report that has since been discredited, which alleged that comorbidity procedures had falsely inflated the number of COVID-19 deaths in the U.S. (Rouan, 2021). Misinformation about a link between 5G and COVID-19 quickly spread online on social media sites such as Twitter through the viral hashtag #5GCoronavirus and resulted in the destruction of 5G towers by conspiracy theorists (Ahmed et al., 2020). More than 2 years into the pandemic, new COVID-19 CTs continued to circulate, including a claim furthered by both a former NBA athlete and a U.S. senator for the state of Wisconsin that professional athletes were dying after being vaccinated (Cillizza, 2022).

Conspiracies: effects on health-related behaviors

Previous research has established that holding conspiratorial beliefs about the COVID-19 virus is inversely related to the likelihood that someone will take preventative measures or get vaccinated against the virus (Romer and Jamieson, 2020). Additionally, individuals who were exposed to anti-vaccination conspiratorial beliefs were initially more likely to believe vaccines were unsafe (Hornsey et al., 2020). Social media usage has also been identified as a factor that influences individuals' conspiratorial thinking about COVID-19. Individuals who use social media as their primary source of information about COVID-19 are more likely to believe CTs about the virus and are less likely to take preventative measures (Allington et al., 2021). However, individuals who believe CTs about COVID-19 will engage in preventative measures if they are not government-driven (Marinthe et al., 2020). Some extreme preventative behaviors became CTs themselves during 2020. An online survey of over 500 U.S. adults conducted by the CDC found that approximately one-third of survey respondents had inhaled or ingested bleach or applied it to their food or skin in an effort to prevent COVID-19 (Gharpure et al., 2020). Research has also shown that individuals who believed hydroxychloroquine could cure or prevent COVID-19 were more likely to engage in conspiratorial ideation (Bertin et al., 2020).

Conspiratorial beliefs have been previously linked to vaccine hesitation beyond the context of the COVID-19 pandemic. Despite evidence to the contrary, for over two decades, there has been a persistent belief among the anti-vaccination community that vaccines, and specifically the measles, mumps, and rubella (MMR) vaccine, cause autism (Gross, 2009). Belief in this CT has resulted in lowered immunization rates and recurrent outbreaks of measles, which had previously been declared to have been eliminated thanks to high vaccination rates (Gross, 2009). Several studies have also linked conspiratorial beliefs with lower human papillomavirus (HPV) immunization rates. Exposure to conspiratorial messages about the HPV vaccine has been found to result in less favorable attitudes toward the vaccine and lower vaccination intentions (Chen et al., 2021), and previous research shows that parents with high levels of conspiratorial thinking are more likely to delay vaccination for their children (Callaghan et al., 2019). Finally, individuals who endorse general anti-vaccine CTs, such as "immunizations allow governments to track and control people" and "tiny devices are implanted in vaccines for use in mind control experiments," have been found to have lower vaccine intentions for any virus than individuals who do not believe anti-vaccine CTs (Jolley and Douglas, 2014).

Belief in COVID-19 CTs has also been shown to reduce adherence to social distancing measures (Bierwiaczonek et al., 2020). It has been negatively associated with safeguarding behaviors that can reduce the spread of the virus, such as hand washing and mask wearing (van Mulukom et al., 2022). A failure to adhere to health professionals' guidelines is consistent with the effects of belief in other health-related CTs. Research has shown that high levels of conspiracism correlate with avoidance of medical professionals, such as annual examinations by a physician or a dentist (Oliver and Wood, 2014). However, which CT individuals believe may impact their behavior and result in differing levels of health-related risk taking. For example, one study conducted in both the U.S. and the U.K. indicated that while individuals who believed that COVID-19 is a hoax were less likely to report engaging in proactive behaviors such as handwashing and social distancing, those who believed that it originated in a laboratory were more likely to rely on alternative remedies (Imhoff and Lamberty, 2020).

Factors impacting beliefs in conspiracy theories

In order to look for potential successful solutions, it is important to identify how belief in CTs may lead to decreased health-related behaviors and to investigate the sources of such beliefs. When it comes to individual characteristics of audience members susceptible to misinformation, existing literature has identified that different types of variables can impact beliefs in misinformation (general and COVID-19 specific), ranging from cognitive and psychopathological variables, media-related and health-related variables, emotion variables, to demographics, which might impact beliefs in CTs about COVID-19 and vaccines.

Regarding *cognitive variables*, by investigating the psychological profile of individuals who tend to fall prey to misinformation using online surveys, Pennycook et al. (2020) found that individuals' cognitive "bullshit receptivity" (p. 189) is driven by their varied degree of reflexive open-mindedness, defined as "tendency to be overly accepting of weak claims" (p. 185). Such cognitive tendency can be manifested as (a) perceiving misinformation as accurate, (b) inability to discern the differences between real news and fake news, and (c) over-claiming one's knowledge of the focal topic. *Trust* was found to be another cognitive predictor of conspiracy beliefs. As summarized by van der Linden et al. (2021), according to previous misinformation research findings, individuals tend to trust claims made by sources whose ideology are congruent with their own while discounting those from politically incongruent sources; as a result, the persuasiveness of misinformation might be boosted or retracted depending on whether individuals support the sources or not.

Researchers have also identified *psychopathological* var*iables*, including Machiavellianism and collective narcissism, that lead to outgroup aggression (de Zavala et al., 2020; de Zavala et al., 2009), as well as individual susceptibility to conspiracy beliefs and intentional spread of CTs during the COVID-19 pandemic (Hughes and Machan, 2021). In their attempt to understand intergroup aggressiveness, de Zavala et al. (2009) posited the concept of collective narcissism as "an emotional investment in an unrealistic belief about the in-group's greatness" (de Zavala et al., 2009, p. 1,074), later adding "resentment for insufficient external recognition of the in-group's importance" (de Zavala et al., 2020, p. 741). According to de Zavala et al.'s (2020) studies, collective narcissism (a) predicts aggression against out-groups and (b) is related to "high private and low public collective self-esteem and low implicit group esteem" and "sensitivity to threats to the ingroup's image and retaliatory aggression" (p. 1,074). Besides collective narcissism, Hughes and Machan (2021) further examined trait psychopathy. High Machiavellianism and primary psychopathy, manifested in "callousness and lack of emotion and secondary psychopathy" and characterized by "impulsivity and anti-social tendencies," were found to predict more general and COVID-19-specific conspiracy beliefs (Hughes and Machan, 2021). Interestingly, in the same study, collective narcissism only predicted COVID-19-specific conspiracy beliefs but not general conspiracy beliefs (Hughes and Machan, 2021).

Media-related variables and *health-related* variables are found to predict misinformation beliefs, especially under the influence of disinformation campaigns (Lukito, 2020), including anti-vaccine CT spread (Jolley and Douglas, 2014). By analyzing activities of Russia's Internet Research Agency (IRA) in U.S. social media (2015–2017), Lukito (2020) found IRA's internally-coordinated multi-platform disinformation campaign activity on Reddit and Twitter, targeted at U.S. citizens, alerting the future of "increasingly complex disinformation campaigns, executed by countries who take advantage of the internet's anonymity and viral possibilities to spread inciteful messages" (p. 250) and a more CT saturated disinformation landscape. Anti-vaccine-specific CTs, their spread on social media, and predictors of anti-vaccine conspiracy beliefs have been examined. For instance, Jolley and Douglas's (2014) study with UK participants showed: (a) a significant negative relationship between anti-vaccine conspiracy beliefs and vaccination intentions; (b) this negative relationship was mediated by perceived dangers of vaccines, feelings of powerlessness and disillusionment, and mistrust in authorities. These health-related variables seem to indicate that vaccine perception, self-perceived power/powerlessness, and (mis)trust in public health authorities are important factors predicting conspiracy beliefs related to vaccine and anti-vaccine disinformation campaigns.

Focusing on anti-vaccine conspiracy beliefs, via an online survey among parents, Tomljenovic et al. (2020) further examined *emotional* variables in the context of comparing the impacts of analytically rational and experientially intuitive thinking styles, as well as the role of emotional functioning (i.e., optimism) and emotions toward vaccines, on participants' child vaccine conspiracy beliefs. This study identified three factors associated with greater vaccine conspiracy beliefs: (a) stronger predisposition to react with negative emotions toward vaccination; (b) greater experientially intuitive thinking; (c) lower levels of education, highlighting the importance of emotions and different thinking styles, as well as the role of demographic factors, in understanding CT belief regarding vaccines, including COVID-19 vaccines.

Vijaykumar et al.'s (2021) study further echoed the importance of *demographics* in COVID-19 misinformation management, with age as the focal demographic factor that is associated with misinformation susceptibility and predicts COVID-19 misinformation beliefs. Based on online experiments conducted among adult WhatsApp users in the UK and Brazil, Vijaykumar et al. (2021) found that, in both countries, younger adults were more likely to (a) believe COVID-19 misinformation and (b) share such misinformation than older adults.

Despite the increasing knowledge on the effects of the factors contributing to health misinformation belief (general and COVID-19), how these factors might function together (with varied strengths among different factor groups) and which of these groups of variables might be most important in predicting beliefs in COVID-19 CTs, as well as their impacts on health behavioral outcomes, remain understudied. In order to fill this gap in the literature of health communication, we ask the following research questions:

> RQ1: Which is the strongest individual-level predictor of the COVID-19 conspiratorial beliefs?
>
> RQ2: Which is the strongest individual-level predictor of health-related behaviors (i.e., proactive behavior, avoidance behavior, and actual vaccination)?

Individual-level factors, including psychological factors and emotions, have been shown to impact vaccine acceptance directly and sometimes adversely. Some studies have found that the feelings of fear of dying, anguish, vulnerability, and insecurity could lead to higher

levels of confidence and propensity to COVID-19 vaccination (Kang and Jung, 2020; Mannan and Farhana, 2020; Simione et al., 2021), while others have shown that anger and negative emotions could be related to lower levels of vaccine acceptance (Betsch and Böhm, 2016; Sun et al., 2021). In addition, previous literature points out that key factors in determining the influence of emotions and psychological factors on COVID-19 vaccine propensity could be conspiracy beliefs, mistrust, or skepticism (Chou and Budenz, 2020). Simione et al. (2021) further showed that death anxiety reduced the propensity to get vaccinated through a mediated path in believing in CTs; psychological distress reduced vaccination propensity by increasing both conspiracy beliefs and mistrust; whereas anxiety increased the propensity to get vaccinated through a decrease in both belief in CTs and mistrust in science. These results suggest that individual-level variables, including psychological and emotional dimensions, are differently related to beliefs in CTs and propensity to get vaccinated. Further investigation is needed to determine if and how the belief in COVID-19 CTs mediate the relationship between individual-level variables and health-related behaviors. Thus, we ask the following research question:

> RQ3: How, if at all, does the belief in COVID-19 CTs mediate the relationship between its strongest individual-level predictor and health-related behaviors (i.e., proactive behavior, avoidance behavior, and actual vaccination)?

Method

Participants and recruitment

In October and November 2021, we conducted an online survey with a total of 1,024 U.S. adults recruited from a Qualtrics panel, using the proportional quota sampling method to match the age, gender, and race distributions of US population[1] Since this study was designed to understand adult individuals' COVID-19 and COVID-19 vaccine-related beliefs and behavioral intentions, screeners were placed. The first screened out the participants who did not want to indicate their vaccination status (4) (1: Have not been vaccinated against COVID-19; 2: Have received only the first dose of the COVID-19 vaccine (if your vaccine requires two doses); 3: Have received both doses of the COVID-19 vaccine; 4: Do not want to indicate any of the above). Then the following three screeners screened out all those who did not intend to vaccinate or fully vaccinate in the future regardless of their initial vaccination status indicated in the first screener. This was done to capture the adopters (i.e., who have already taken the vaccine) and hesitant adopters (i.e., who have not taken the vaccine, but intended to do it). We purposefully excluded definite vaccine rejectors as we estimated that they were likely to hold extreme and stable conspiracy beliefs as well as health-related behaviors.

Respondents had ages ranging from 18 to 81 (M = 49.91, SD = 16.87). The sample contained 566 (55.3%) females, 455 (44.4%) males, and 2 (0.2%) respondents identifying their gender as other. One respondent declined to report gender. The majority of the sample was White 691 (67.5%), whereas 120 participants (11.7%) were Black, 118 (11.5%) Hispanic, 62 (6.1%) Asian, 11 (1.1%) were American Indian or Alaska native, and 20 (2%) identified as some other race. Two respondents refused to answer. Three hundred seventy-three participants (36.4%) had a high school degree, 283 (27.6%) had a bachelor's degree, 207 (20.2%) had an associate degree, 136 (13.3%) had a master's degree, 19 (1.9%) had a doctoral degree, 3 (0.3%) had less than elementary school education, 1 (0.1%) respondent had an elementary school degree. Two respondents declined to report their education level. In terms of the average earning of household, 460 (44.9%) respondents reported household income less than $50,000, 192 (18.8%) reported $50,000 to $69,999, 171 (16.7%) reported $70,000 to $100,000, 182 (17.8) reported household earning more than $100,000, and 19 respondents declined to answer. For political party identification, 510 (49.8%) reported their identification with Democratic, 238 (23.2%) identified with Republican, 226 (22.1%) identified with Independent, 37 (3.6%) reported no party identification, 7 (0.7%) identified with some other party, and 6 (0.6%) refused to answer. Research has been approved by the University of Georgia Institutional Review Board.

Predictor variables

To assess analytical thinking, respondents were asked to answer seven problem-solving questions (e.g., "If you are running a race and you pass the person in second place, what place are you in?"). For each problem, participants got one point if they provided the correct answer. The scores were added up to obtain a final score for each participant, ranging between 0 and 7 (N = 1,023, M = 1.69, SD = 1.69).

Psychopathy was measured with a seven-point Likert scale ranging from strongly disagree (1) to strongly agree (7) with 26 items (N = 874, M = 2.82, SD = 1.00, α = 0.90). Example items include "Success is based on survival of the fittest; I am not concerned about the losers" and "For me, what's right is whatever I can get away with" (Levenson et al., 1995).

Collective narcissism was measured using a seven-point Likert scale ranging from strongly disagree (1) to strongly agree (7) with nine items (N = 971, M = 3.63, SD = 1.34, α = 0.87). Respondents were asked to answer the question having in mind the national group with which they identify. Example items include "I wish other groups would more quickly recognize the authority of my group" and "My group deserves special treatment" (de Zavala et al., 2009).

Machiavellianism was measured using four sub-scales (i.e., amorality, desire for control, desire for status, distrust of others) with a total of 16 items. Respondents were asked to indicate their degree of agreement/disagreement on a seven-point Likert scale ranging from strongly disagree (1) to strongly agree (7) (N = 975, M = 3.00, SD = 1.25, α = 0.92). The items (e.g., "I like to give the orders in interpersonal situations") were adopted from Dahling et al. (2009).

General belief in CTs was measured with 15 items taken from Brotherton et al. (2013). Participants were asked to rate statements on a seven-point Likert scale ranging from definitely not true (1) to definitely true (7) (N = 990, M = 3.38, SD = 1.57, α = 0.96). Example items included "The government is involved in the murder of innocent citizens and/or well-known public figures, and keeps this a secret."

1 Some participants declined to answer some of the questions in the survey, leading to a varied sample size across different variables. The sample size for each variable was shown alongside the measurement.

Trust in the government was measured on a scale from not at all (1) to complete trust (7) (N = 1,016, M = 4.10, SD = 1.64). Respondents were asked to indicate to what extent they think they can trust the government in Washington, D.C. to do what is right.

News media trust was measured with a seven-point Likert scale ranging from strongly disagree (1) to strongly agree (7) (N = 977, M = 4.96, SD = 1.25, α = 0.95). Respondents were asked to think about news media in the United States in general and their coverage of the COVID-19 pandemic to rate their level of agreement/disagreement with 16 items adapted from Kohring and Matthes (2007). Example statement included "the topic of COVID-19 receives necessary attention."

Perceived severity of COVID-19 was measured with three items adapted from Zhao and Tsang (2022) on a seven-point Likert scale ranging from strongly disagree (1) to strongly agree (7). Items included "COVID-19 is serious," "COVID-19 can cause death," and "COVID-19 is more severe than most people realize" (N = 1,003, M = 6.35, SD = 1.09, α = 0.85).

Vaccine confidence in COVID-19 was measured with three items taken from Nowak et al. (2018). Respondents were asked to indicate their level of confidence about the COVID-19 vaccine on a scale from not confident at all (1) to completely confident (7). Items included "How confident are you in the safety of the COVID-19 vaccine or shot?" "How confident are you that you would benefit from receiving a COVID-19 vaccine or shot?" and "How confident are you in the effectiveness of the COVID-19 vaccine or shot?" (N = 1,016, M = 5.76, SD = 1.42, α = 0.95).

Sensation seeking was measured with eight items taken from Hoyle et al. (2002) on a seven-point Likert scale ranging from strongly disagree (1) to strongly agree (7). Example items included "I would like to explore strange places" and "I would like to take off on a trip with no pre-planned routes or timetables" (N = 1,012, M = 3.38, SD = 1.48, α = 0.88).

Anxiety trait was measured using five items taken from Zsido et al. (2020) on a seven-point Likert scale ranging from strongly disagree (1) to strongly agree (7). Example items included "I feel that difficulties are piling up so that I cannot overcome them" and "I worry too much over something that really does not matter" (N = 1,014, M = 3.52, SD = 1.67, α = 0.91).

The fear trait was measured with 22 items taken from Bernstein and Allen (1969). Respondents were asked to indicate how much fear each item causes them on a seven-point scale ranging from none (1) to terror (7). Example items included "death of a loved one" and "speaking before a group" (N = 984, M = 3.79, SD = 1.24, α = 0.94).

Outcome variables

COVID-19 conspiratorial belief was measured with seven items adapted from Brotherton et al. (2013). Participants were asked to rate the following statements about the COVID-19 pandemic on a seven-point Likert scale ranging from definitely not true (1) to definitely true (7). Example items included "I believe there are groups interested in spreading panic to achieve their own goals" and "I believe that the development of the pandemic may benefit certain groups of whose interests we have no idea" (N = 997, M = 3.79, SD = 1.74, α = 0.92).

Avoidance behavior was measured with six items taken from Zhao and Tsang (2022). Respondents were asked to indicate how often they have been engaging in the following preventive behaviors during the COVID-19 pandemic on a seven-point scale ranging from never (1) to all the time (7). Example items included "avoiding close contact with people who are sick" and "avoiding dining out" (N = 1,009, M = 5.55, SD = 1.31, α = 0.86).

Proactive behavior was measured with three items taken from Zhao and Tsang (2022). Participants were asked to indicate how often they have been engaging in the following preventive behaviors during the COVID-19 pandemic on a seven-point scale ranging from never (1) to all the time (7). Items included "washing your hands more often," "washing your hands appropriately (about 20 s using soap)," and "covering coughs and sneezes" (N = 1,019, M = 6.20, SD = 1.04, α = 0.83).

Actual vaccination was measured with one question that asked participants about their COVID-19 vaccination status. The options included "have not been vaccinated against COVID-19" (coded as "1"), "have received only the first dose of the COVID-19 vaccine (if your vaccine requires two doses)" (coded as "2"), and "have received both doses of the COVID-19 vaccine" (coded as "3"; N = 1,024, M = 2.85, SD = 0.48).

Analysis

Hierarchical regression analyses were run to answer RQ1 and RQ2, controlling for age, gender, race, political ideology, level of education, income, personal religiosity, pregnancy status, and state of residency. RQ3 was answered using a simple mediation model [PROCESS macro model (4) with 5,000 bootstrap samples (Hayes, 2013)].

Results

RQ1 asked which individual-level variable best predicted the COVID-19 conspiratorial beliefs. The multicollinearity assumption was held as all variance inflation factor (VIF) values were lower than 4, and no tolerance value was below 0.2. The P–P plot of standardized residuals and the scatterplot of standardized residuals against standardized predicted values showed that the assumptions of residual normality and homoscedasticity were met. A multiple regression analysis with hierarchical entry was conducted to predict the COVID-19 conspiratorial beliefs using individual-level variables while controlling for demographic factors. The control variables (i.e., age, gender, race, political ideology, education, household income, personal religiosity, pregnancy status, state of residency) accounted for a significant amount of the variance in COVID-19 conspiratorial beliefs, R^2 = 0.18, $F(9,664)$ = 16.32, $p < 0.001$. After entering analytical thinking, psychopathy, collective narcissism, Machiavellianism, anxiety trait, fear trait, general belief in CTs, trust in the government, trust in news media, perceived severity of COVID-19, vaccine confidence in COVID-19, and sensation seeking, the model accounted for 73.1% of the variance in COVID-19 conspiratorial beliefs, $F(21,652)$ = 84.39, $p < 0.001$. The second step, individual-level variables accounted for an additional 55% of the variance in COVID-19 conspiratorial beliefs, R^2 change = 0.55, F change (12,652) = 111.09. In the complete model, general belief in CTs was the best individual predictor (β = 0.68, $p < 0.001$). Individuals'

collective narcissism ($\beta = 0.06$, $p = 0.046$) and Machiavellianism ($\beta = 0.08$, $p = 0.043$) were also positively associated with COVID-19 conspiratorial beliefs. Trust in the government ($\beta = -0.09$, $p < 0.001$) and news media ($\beta = -0.07$, $p = 0.018$) were negatively associated with COVID-19 conspiratorial beliefs (see Table 1).

RQ2 asked which one, among all individual-level variables, best predicted health-related behaviors. Three multiple hierarchical regression analyses were conducted to predict the proactive behavior, avoidance behavior, and actual vaccination, separately. Firstly, the results showed that the control variables (age, gender, race, political ideology, education, household income, personal religiosity, pregnancy status, state of residency) accounted for a significant amount of the proactive behavior variance, $R^2 = 0.07$, $F(9,666) = 5.25$, $p < 0.001$. After entering analytical thinking, psychopathy, collective narcissism, Machiavellianism, general belief in CTs, trust in the government, trust in news media, perceived severity of COVID-19, vaccine confidence in COVID-19, sensation seeking, and anxiety trait, and fear trait, the model accounted for 23.5% of the variance in proactive behaviors $F(21,654) = 9.58$, $p < 0.001$. The second step, individual-level variables accounted for an additional 16.9% of variance in proactive behaviors, R^2 change = 0.17, F change (12,654) = 12.04. Controlling for demographic factors, the perceived severity of COVID-19 was the best individual predictor ($\beta = 0.27$, $p < 0.001$). In addition, analytical thinking ($\beta = -0.08$, $p = 0.03$) and psychopathy ($\beta = -0.25$, $p < 0.001$) were negatively associated with proactive behaviors. Confidence in COVID-19 vaccines ($\beta = 0.13$, $p = 0.004$) and fear trait ($\beta = 0.10$, $p = 0.015$) were positive predictors of proactive behaviors (see Table 2).

Second, when it comes to the avoidance behavior, demographic factors such as age, gender, race, political ideology, education, household income, personal religiosity, pregnancy status, and state of residency accounted for a significant amount of the avoidance behavior variance, $R^2 = 0.10$, $F(9,663) = 7.90$, $p < 0.001$. After entering the second step, individual-level variables, the model accounted for 32.9% of the variance in avoidance behaviors, $F(21,651) = 15.18$, $p < 0.001$. These variables accounted for an additional 23.2% of variance in avoidance behaviors, R^2 change = 0.23, F change (12,651) = 18.73. Among them, the perceived severity of COVID-19 was the best individual predictor ($\beta = 0.35$, $p < 0.001$), followed by the trust in the news media ($\beta = 0.21$, $p < 0.001$), sensation seeking ($\beta = -0.14$, $p < 0.001$), and fear trait ($\beta = 0.09$, $p = 0.02$) (see Table 3).

Third, in terms of one's actual vaccination behavior, demographic factors accounted for a significant amount of variance, $R^2 = 0.04$, $F(9,668) = 3.15$, $p < 0.001$. After entering analytical thinking, psychopathy, collective narcissism, Machiavellianism, general belief in CTs, trust in the government, trust in news media, perceived severity of COVID-19, vaccine confidence in COVID-19, sensation seeking, anxiety trait, and fear trait, the model accounted for 9.5% of the variance in actual vaccination behavior, $F(21,656) = 3.29$, $p < 0.001$. The second step, individual-level variables accounted for an additional 5.5% of variance in actual vaccination behavior, R^2 change = 0.06, F change (12,656) = 3.30. When controlling for demographic factors, confidence in the COVID-19 vaccine was the best predictor for one's actual vaccination behavior ($\beta = 0.21$, $p < 0.001$). Additionally, collective narcissism was positively associated with actual vaccination ($\beta = 0.12$, $p = 0.02$). Trust in news media ($\beta = -0.11$, $p = 0.04$) and sensation seeking ($\beta = -0.10$, $p = 0.04$) were negatively associated with one's actual vaccination behavior (see Table 4).[2]

Based on the results of RQ2, the strongest predictor of belief in COVID-19 CTs was the belief in other CTs (i.e., general CTs). RQ3 sought to investigate whether and how the beliefs in COVID-19 CTs mediate the relationship between belief in general CTs and health-related behaviors. The linear regression with the PROCESS macro model 4 was used to analyze how belief in general CTs influences proactive behavior, avoidance behavior, and actual vaccination behavior, respectively, through belief in COVID-19 CTs. The demographic factors, including age, sex, race, education, household income, political ideology, personal religiosity, pregnancy status, and state of residency, were controlled for. There was no significant direct effect of belief in general CTs. However, belief in COVID-19 CTs served as a significant predictor of avoidance behavior ($b = -0.17$, $p < 0.001$). We found a significant indirect effect of belief in general CTs on avoidance behavior through belief in COVID-19 CTs [point estimate = −0.15, *BootSE* = 0.04, Boot95% CI = (−0.23, −0.07)]. The relationship between belief in general CTs and avoidance behavior was

TABLE 1 Summary of hierarchical regression analysis predicting conspiracy beliefs in COVID-19.

Predictor		R^2 change	β
Step 1			
	Control variables[a]	0.18***	
Step 2			
	Analytical thinking	0.55***	−0.02
	Psychopathy		−0.05
	Collective narcissism		0.06*
	Machiavellianism		0.08*
	General belief in conspiracy theories		0.68***
	Trust in the government		−0.09***
	Trust in news media		−0.07*
	Perceived severity of COVID-19		−0.04
	Vaccine confidence in COVID-19		−0.04
	Sensation seeking		0.02
	Anxiety		0.04
	Fear		−0.04
Total R^2		0.73***	
N		674	

[a]Control variables included age, gender, race, political ideology, level of education, income, personal religiosity, pregnancy status, and state of residency. Standardized coefficients were reported. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

2 As a side analysis, we coded the results of our open-ended question which asked the participants to indicate the reason for which they vaccinated. The results indicated that most of them did it for prevention purposes – to protect themselves and their loved ones (54.7%), because they had a underlying health condition (11.2%), because they were forced to do so (7.1%), or because it was a smart thing to do and they trusted science (6.5%).

TABLE 2 Summary of hierarchical regression analysis predicting proactive behaviors.

Predictor		R^2 change	β
Step 1			
	Control variables[a]	0.07***	
Step 2			
	Analytical thinking	0.17***	−0.08*
	Psychopathy		−0.25***
	Collective narcissism		−0.07
	Machiavellianism		0.09
	Anxiety trait		−0.06
	Fear trait		0.10*
	General belief in conspiracy theories		0.08
	Trust in the government		0.01
	Trust in news media		0.03
	Perceived severity of COVID-19		0.27***
	Vaccine confidence in COVID-19		0.13**
	Sensation seeking		−0.01
Total R^2		0.24***	
N		676	

[a]Control variables included age, gender, race, political ideology, level of education, income, personal religiosity, pregnancy status, and state of residency. Standardized coefficients were reported. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

TABLE 3 Summary of hierarchical regression analysis predicting avoidance behavior.

Predictor		R^2 change	β
Step 1			
	Control variables[a]	0.10***	
Step 2			
	Analytical thinking	0.23***	−0.01
	Psychopathy		−0.09
	Collective narcissism		−0.04
	Machiavellianism		0.05
	Anxiety trait		0.06
	Fear trait		0.09*
	General belief in conspiracy theories		−0.01
	Trust in the government		0.07
	Trust in news media		0.21***
	Perceived severity of COVID-19		0.35***
	Vaccine confidence in COVID-19		−0.04
	Sensation seeking		−0.14***
Total R^2		0.33***	
N		673	

[a]Control variables included age, gender, race, political ideology, level of education, income, personal religiosity, pregnancy status, and state of residency. Standardized coefficients were reported. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

fully mediated by belief in COVID-19 CTs (see Figure 1). Also, no significant mediation was detected on either the relationship between belief in general CTs and proactive behavior [point estimate = 0.01, *BootSE* = 0.03, Boot95% CI = (−0.05, 0.07)] or the relationship between belief in general CTs and actual vaccination behavior [point estimate = 0.00, *BootSE* = 0.02, Boot95% CI = (−0.03, 0.04)].

Discussion

This study comprehensively examined individual-level predictors of COVID-19 conspiracy beliefs and related health behaviors in a national sample of U.S. adults. Skepticism can be productive and useful for democratic societies. Political philosophers argue that a skeptical way of believing is "an intellectual prerequisite of democracy" (p. 16) as it allows us to challenge the opinions of others, while demanding responsibility to consult reason and evidence when producing political judgments (Talisse, 2008). However, regular monitoring of the work of elites (e.g., through investigative journalism) and a healthy dose of civic suspicion toward the motives of those who hold positions of power differ from conspiratorial thinking, which tends to explain *all* social phenomena through the lens of grand conspiracies. Individuals engaged in this line of thinking exit the realm of skepticism to enter dogmatism, which avoids sources of disconfirmation in an attempt to preserve a preferred worldview. In these instances, CTs proper, as Baden and Sharon (2021) call them, become dangerous mutilations of ascertained knowledge. Such mutilations can saturate extremist and populist political discourses and gain pathological and paranoid qualities. This study showed the importance of studying conspiratorial beliefs in assessing new health communication phenomena, such as information disorders associated with COVID-19. According to Sellnow et al. (2019), information disorders are "intentionally and verifiably false" claims strategically distributed to broad audiences, resulting in disrupted public communication based on factual information and the normal discourse of renewal in risk and crises. They further cited that information disorders encompass "rumors, CTs and fabricated information" that, through digital connectivity, are broadly distributed and noticed due to their "shock value" (Wardle and Derakhshan, 2017, p. 10).

The results indicated that belief in other CTs best predicted whether an individual would be likely to believe that COVID-19 has been a product of a secret group of malevolent actors that pursues a hidden plot with the intent to secure or strengthen its own power. This variable emerged as the most important even when an entire set of other individual-level variables were entered into the equation, including demographics, psychopathological variables, emotion traits, cognitive variables, trust perceptions, and health-related variables. The predictive power of the model was high, as it explained significant 73% of variance in belief in COVID-19 CTs. Our research supports the findings of previous studies that people who believe in one CT are more likely to believe in another (e.g., Bruder et al., 2013; Dyrendal et al., 2021), which indicates a conspiracy spillover effect.

TABLE 4 Summary of hierarchical regression analysis predicting actual vaccination behavior.

Predictor		R^2 change	β
Step 1			
	Control variables[a]	0.04***	
Step 2			
	Analytical thinking	0.06***	0.03
	Psychopathy		0.05
	Collective narcissism		0.12*
	Machiavelism		−0.03
	Anxiety trait		0.03
	Fear trait		−0.07
	General belief in conspiracy theories		0.02
	Trust in the government		−0.09
	Trust in news media		−0.11*
	Perceived personal risk of COVID-19		0.03
	Vaccine confidence in COVID-19		0.21***
	Sensation seeking		−0.10*
Total R^2		0.10***	
N		678	

[a]Control variables included age, gender, race, political ideology, level of education, income, personal religiosity, pregnancy status, and state of residency. Standardized coefficients were reported. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

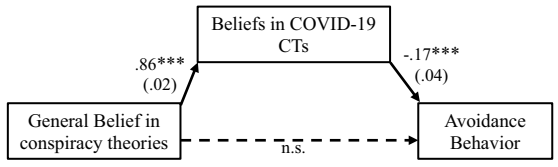

FIGURE 1
Mediation model with unstandardized coefficients. $N = 880$. Age, gender, race, education, household income, political ideology, personal religiosity, pregnancy status, and state of residency are included as exogenous variables and controlled in the model. However, the results associated with these variables are not included here in the Figure in the interest of presentation parsimony. Significant paths are presented with solid lines. Non-significant paths are presented with dotted lines. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

In addition, our results showed that the belief in COVID-19 CTs leads to lower avoidance behaviors such as social distancing, possibly because some CTs discourage this behavior. These findings not only support the findings of previous studies about congruency between attitudes and behaviors (see Ajzen and Sexton, 1999) but could also show a stronger general tendency to utilize CT as a generic explanation for social phenomena, including health-related ones. It also might suggest that a belief in CTs might be path-dependent, persisting alongside evidence that falsifies it. It might be that certain mental conspiratorial models are formed that are transferred and applied to explanations of the majority of social phenomena, especially the ones that are novel and thus subject to a plentitude of interpretations. The danger of possible path dependency in conspiratorial beliefs lies in the possibility that the dogmatic logic of explaining all phenomena by a conspiracy leaves no room for falsification. These findings underscore the complexity of the relationship between CTs and health behaviors and highlight how easily skepticism can devolve into harmful CTs that threaten public well-being.

Traditional approaches to correcting health misinformation may be insufficient to address the conspiracy theory spillover effect consistent with our study's findings. Our results suggest that among U.S. adults, beliefs in other/general CTs lead to beliefs in specific CTs about one focal health issue (COVID-19). Further research should examine if this chain reaction of misbeliefs is true in other areas of health information. Additionally, given that most health misinformation correction focuses on correcting misperception (e.g., van der Meer and Jin, 2020), how to elevate misinformation correction at the misbelief management level needs to be further addressed by health communication scholars and practitioners. To prevent and/or contain the CT spillover effect as detected in our study, and to remove belief-system created obstacles in accurate health information dissemination, health agencies and public health information officers might consider implementing more proactive health literacy education, with an increased emphasis on debunking general CTs before new health issues emerge and intertwine with new specific CTs, prohibiting protective action taking. Interventions should aim to promote healthy skepticism that encourages critical thinking and informed decision-making in a democracy, while simultaneously combating the spread of dangerous CTs.

Our results further indicate that the perceived severity of COVID-19 was the best individual predictor for proactive health behavior, which included washing one's hands appropriately and more often and covering one's sneezes, as well as for avoidance behaviors, which included a range of COVID-19 avoidance measures, such as avoiding close contact with people who are sick and avoiding dining out. This indicates that among the large number of individual-level variables, perceived severity of a potentially deadly disease will outweigh all other factors in predicting some health-related behaviors. In other words, if individuals consider that a disease is severe and dangerous, regardless of their other psychopathological, emotional, cognitive, or trust characteristics, they are more likely to engage in a set of behavioral measures that would prevent such an outcome. Perceptions of disease threat are often closely compared to fear traits in predicting behavioral outcomes in health and medicine. Our findings indicate that fear traits were positively associated with predicting both proactive and avoidance behaviors, suggesting that individuals who are generally more fearful would engage more often in behaviors considered to help protect them from COVID-19. Although there is a considerable and impressive body of research in the area of health psychology that predicts health behaviors, perceptions of illness threat are one of the important factors of social-cognition models that examine various aspects of an individual's cognitions to predict future health-related behaviors and outcomes (for review see Conner and Norman, 2005). Our study supports those claims for proactive and avoidance behavior regarding COVID-19. However, for actual vaccination behavior, our study found that confidence in COVID-19 vaccines was a better predictor. This finding aligns

with the vaccine hesitation literature, which warned that misinformation about vaccines (e.g., false claims about the link between MMR and vaccine autism; false claims about the HPV vaccine) can impact immunization behavior (e.g., Chen et al., 2021; Gross, 2009). Further studies are needed to distinguish between possible singularity of willingness to vaccinate from other health-related behaviors and its connection to vaccines-related CTs.

Limitations and future directions

There are several limitations of the current study to be addressed in future studies. First, we collected data in October and November 2021, at one specific point in time, only during the ongoing, prolonged COVID-19 pandemic. Before and after the data collection time period, there have been informational, perceptual, and behavioral fluctuations among individuals and their responses to health communication messages. Longitudinal studies and/or temporal comparisons on how different clusters of factors impacting general and COVID-19-specific CTs and health-related behaviors will shed further light on the evolving pattern of CT spillover. Second, the current study was conducted among U.S. adults. Given the prevalence of CTs and their impacts across countries and contingents, the extent to which the strongest predictors of conspiratorial beliefs function and how the CT spillover effect mutates in different cultural and socio-economic contexts is yet to be fully examined. Third, the timing of the recruitment occurred after the vaccines were widely available and often mandated. In addition, our screener questions resulted in having predominantly those who have received two doses of vaccines (90.4%), while those who received one dose (4.3%) and unvaccinated individuals (5.3%) were in the minority. While those screener questions might have contributed to the avoidance of the ceiling effect in data and overrepresentation of those holding extreme views on COVID-19-related issues, they might have led to skewed results in the model with actual vaccination behavior. The results of this study regarding the actual vaccination model should thus be interpreted with this limitation in mind. Fourth, the sample of our study includes some demographic biases: Republicans (23.2%), Democrats (49.8%), and Independents (3.6%) relative to the U.S. population. Gallup data for 2021 showed that 27% of Americans declared themselves as Republicans, 42% as Independents, and 29% as Democrats (Gallup, 2024). Having in mind the smaller discrepancy between data for Republicans than between the data for Democrats and Independents, it is possible that in that particular point in time, in the peak of the COVID-19 crisis, and high political polarization in the country, more Independents were likely to proclaim themselves as Democrats possibly to side with Democrats' policies on COVID-19. Although our study did not use political affiliation as a predictor variable, and has controlled for political affiliation to minimize bias, the authors acknowledge that the answers given to the questions in this study might have been painted overly by Democratic perspectives on COVID-19. However, it must be noted that the percentage of Independents in the US population has been relatively stable since 2011 (from 39 to 43%). The demographic profile of our study might indicate that in times of highly contentious public topics (such as COVID-19), the US population might shift toward expressing polarized opinions rather than nuanced reflection. Future studies should include meta-analyses of COVID-19 data to examine whether such polarization has been pronounced in other studies during the pandemic and provide a clear interpretation of the data. Finally, the cross-sectional survey data do not allow for the establishment of causal relationships. This study only identified correlations between independent and dependent variables. The authors limited potential response biases by question ordering in the actual survey (making sure that demographics go at the end, preceded by dependent variables), and by using adequate statistical analyses to control for a set of demographic variables, while examining the effects of independent variables on predictor variables. To establish robust casualty, future studies could use models with longitudinal data or an experimental design.

Data availability statement

The raw data supporting the conclusions of this article will be made available upon request from the authors.

Ethics statement

The studies involving humans were approved by University of Georgia Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

IP: Conceptualization, Investigation, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing. LK: Data curation, Writing – original draft. WZ: Formal analysis, Methodology, Visualization, Writing – original draft. XL: Formal analysis, Methodology, Visualization, Writing – original draft. YJ: Funding acquisition, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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