Review

A Systematic Review of Effective Measures to Resist Manipulative Information About Climate Change on Social Media

Aliaksandr Herasimenka [1,2,*], **Xianlingchen Wang** [1,3] **and Ralph Schroeder** [1]

1   Oxford Internet Institute, University of Oxford, Oxford OX1 2JD, UK; ralph.schroeder@oii.ox.ac.uk (R.S.)
2   Department of Communication and Media, University of Liverpool, Liverpool L69 7ZX, UK
3   Saïd Business School, University of Oxford, Oxford OX1 2JD, UK
*   Correspondence: a.herasimenka@liverpool.ac.uk

Abstract: We present a systematic review of peer-reviewed research into ways to mitigate the spread of manipulative information about climate change on social media ($n = 38$). Such information may include disinformation, harmful influence campaigns, or the unintentional spread of misleading information. We find that the commonly recommended approaches to addressing manipulation of climate change belief include corrective information sharing and education campaigns targeting media literacy. However, most of the relevant research fails to test the approaches and interventions it proposes. We locate research gaps that include a lack of attention to the large commercial and political entities involved in generating and disseminating manipulation; video- and image-focused platforms; and the computational methods used to collect and analyze data. Evidence drawn from many studies demonstrates an emerging consensus about the policies required to resist climate change manipulation.

Keywords: misinformation; manipulation; conspiracy; climate change; systematic review

1. Introduction

Despite solid scientific consensus about the anthropogenic roots and consequences of climate change, false, inaccurate, or misleading online content often confuses the public, undermining support for urgent mitigating policies [1]. This is important because belief in climate change is more easily weakened than strengthened [2]. Terms used to identify and describe such content include 'manipulation', 'misinformation', 'disinformation', 'fake news', or 'propaganda'. Such manipulative content often spreads on social media platforms [3,4], which are a particularly important source of information about climate change for at least a third of the populations of some of the largest economies, compared with other channels [5].

This review discusses this misleading and unreliable content about climate change under the wider umbrella concept of 'manipulative information about climate change', which encompasses phenomena ranging from misleading information to attempts at deliberately distorting the information environment.

Plenty of studies have analyzed who spreads manipulated information online, how it spreads, and its consequences, including experiments that test solutions to this problem. However, we also know that the climate change debate is *particularly* susceptible to the diffusion of such information [6]. This might be linked to the prominence of this issue on media agendas, but the major economic and political interests at stake also play a role.

To progress our understanding of these topics, it is important to synthesize the research into the sources, channels, and other factors of manipulation spread. However, the broader literature on the phenomenon of climate denial online has only recently begun to be systematically analyzed [7]. The field is still missing a systematic review that synthesizes the research into manipulative information about climate change on social media [4]. At the same time, 'the first systematic and critical review of the literature on social media and climate change' was published only in 2019 [8].

Our systematic approach has several advantages compared to recent reviews of communication about climate change on social media [4,8]. It expands and improves on the existing approaches used in the early reviews of climate change manipulation by searching the literature using multiple databases, undertaking a search with multiple terms, detailing the methodology used, and following the recommendation of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [9]. Our review also focuses on what is currently perhaps the most problematic environment where climate change manipulation originates, that is, social media platforms.

We found that the commonly recommended approaches to addressing manipulation of climate change belief include corrective information sharing and education campaigns targeting media literacy. However, most of the existing publications did not test the approaches and interventions they proposed. We identified several research gaps that include a lack of attention to the large commercial and political entities involved in generating and disseminating manipulation; video- and image-focused platforms; and the computational methods used to collect and analyze data.

2. Misinformation and Manipulation

It is necessary to examine what is meant by 'manipulation' in terms of climate change on social media. The literature uses multiple terms to describe the attempts to discredit climate science and sow confusion in the debate on climate change by casting doubt on well-supported evidence and promoting often fallacious interpretations of observations [4]. Treen and colleagues collected several such terms, including 'skeptical discourse', 'contrarian information', and 'denial campaigns'. The most popular of these terms relates to the concept of 'climate skepticism'. Authors often apply this concept to mean those who doubt climate change or reject mainstream climate science, instead of its original meaning referring to judging 'the validity of a claim based on objective empirical evidence', an integral part of the scientific method [4,10]. Such indiscriminate use of terms appears to have negative consequences as it polarizes 'views on climate change [. . .] and do[es] little to advance the unsteady relationship among climate science, society, and policy' [11].

At the same time, our field has experienced a reframing of the debates about communicating on social media with increased interest in such phenomena as misinformation and disinformation [12]. This is also the case of the topic of climate change [4]. The critical difference between 'misinformation' and 'disinformation' is the intention to mislead. The former refers to information that may or may not inadvertently mislead, and the latter is intentional [12]. Hence, using only one of these terms is too restrictive as the intention to mislead is often hard to determine.

Our study casts the distinction between misinformation, disinformation, and climate denialism in a new light. Climate change denialism, or climate skepticism in its unscientific meaning, has been studied quite extensively. However, we argue that the range of this phenomenon requires a broader focus that would encompass both intentional and unintentional attempts to influence the discussion of climate change through reliance on false information. We use the term 'manipulation' as an umbrella concept that was originally defined as 'influencing someone's beliefs, attitudes, or preferences in ways

that fall short of what an empathetic observer would deem normatively appropriate in context' [13]. This concept is appropriate for our aim as it does not imply intentionality like disinformation and does not confuse legitimate scientific judgment and denialism like climate skepticism, but helps to focus on manipulation sources with an economic, political, or social interest in spreading perceptions of climate change that are normatively inappropriate in context.

3. Previous Reviews and Research Questions

The previous research on climate change is extensive, and there are good overviews that address social science research on the topic in general (e.g., Klinenberg, Araos, and Koslov [14]). There is also a large body of research about the public understanding of science [15] and recent meta-analysis studies into the perceptions of climate information that are primarily informed by psychology [1,2,16]. Some earlier work on communicating climate change is about media reporting [17], and more recent reviews focus on communicating 'climate effectively' [18].

A few recent reviews have also analyzed how the use of the internet and social media affect public understanding of and engagement with climate change information. For example, Schäfer [19] and Pearce and colleagues [8] reviewed the literature on social media and climate change, but mentioned misinformation only briefly. The former noted that 'although (or because) many stakeholders participate online, this does not lead to robust scientific information or better debates' [19].

Treen and colleagues [4] conducted an early review of climate change and sources of misinformation, including and going beyond social media. They found that most studies agreed that climate change misinformation has confused the public, led to political inaction, and stalled support for or led to the rejection of mitigation policies. Their research has also shown how even a small amount of misleading climate information, such as a few statistics, is effective in lowering people's acceptance of climate change. Psychology-informed meta-analyses found that values, ideologies, worldviews, and political orientation are the strongest predictors of belief in climate change [16], more than, for example, age or education [1].

These previous literature reviews inform our research questions, though relatively few of these reviews followed the PRISMA guidelines. First, the reviewed studies often contextualize and differentiate between the approaches to examining climate communication by analyzing the prevailing methodologies and the state of the art of the discipline. This helps to identify emerging trends [20]. For example, previous reviews have highlighted the Anglo-American focus of most studies in this area [7].

Second, there has been extensive research on communicating and perceiving climate change information, but this needs to be updated to consider how the public has turned to social media for information where misinformation might flourish. The literature in the broader field of social media misinformation studies considers three key questions: who spreads misinformation, what channels are used, and what can be done [3,21].

These are questions that some literature reviews also partially focus on. For example, Björnberg and colleagues [7] reviewed climate denialism beyond social media platforms and identified six types of sources of denying narratives: denying scientists, governments, media, political and religious organizations, industry, and the public. Treen and colleagues [4] emphasize the role of 'corporate and philanthropic actors with a vested interest [that] provide funding to [...] produce climate change misinformation'. Overall, we now know that many entities have malicious aims in their climate communication, but the identification of these sources of manipulation has been rather rare in the reviews that specifically focus on social media platforms.

Third, the 'channels of spread' question is also at the center of some previous reviews. However, one of the most recent reviews agrees that 'there has been little research specifically into the diffusion of climate change misinformation' [4]. Even more recent reviews in adjacent fields surprisingly give relatively little prominence to social media as a channel of misinformation communication [22]. As with much research on digital communication, the vast bulk of earlier work focuses on Twitter—even though other social media channels are equally, if not more, important in climate change communication [8,23]. The factors that exacerbate the spread of manipulative information are given more prominence, mainly thanks to the efforts of psychologists focusing on different misinformation domains. This research mainly focuses on personal traits, pre-existing beliefs, and ideology.

Finally, the intervention strategies reviewed often focus on broader solutions. Yet few, if any, studies have systematized interventions concerning the problem of manipulation or its manifestations on social media specifically. Björnberg and colleagues [7] name five 'strategies against denialism': the need for change, context-dependent strategies, communication strategies, education, and changing the focus of scientists. Developing critical thinking among the population seems to be the most commonly agreed upon idea to address this [4]. Though, again, these findings are mostly based on data from North America. Several scholars have advanced the general understanding of some appropriate measures that should be taken. These measures range from 'consensus messaging' [18] or 'morality' messaging [2] to targeting people's 'psychological factors' [16]. However, there is a substantial bias towards social psychology-oriented solutions and relatively little discussion of what can be done at the policy and platform governance levels, such as how to communicate relevant messages. Consequently, given the widespread and continuing manipulation campaigns online, how exactly the promotion of such climate change consensus can be achieved remains less clear.

In our systematic review, we go beyond previous literature review studies, both systematic and not systematic, to identify how the research has progressed over time and the current methodologies that dominate the field. We also advance the field by expanding the focus across key areas of social media misinformation studies, using the following research questions:

- How has research into the dissemination of manipulative information about climate change on social media progressed over time, and what methodologies has it adopted?
- What sources and channels involved in disseminating manipulative information about climate change does the literature focus on?
- What factors exacerbating this dissemination does the literature examine?
- What interventions have been proposed and shown to prevent or mitigate the impact of such manipulative information on social media?

4. Methods

Our methodological protocol followed the 2021 PRISMA guidelines. We searched for peer-reviewed articles, books, book chapters, and conference proceedings in two academic databases—Web of Science and SCOPUS (N_{SCOPUS} = 236, N_{WOS} = 142), which contained 128 duplicates. These databases offer a valid instrument for evaluating scholarly publications in social science [24] and have been used in past systematic reviews that asked similar questions [25,26]. We searched for synonyms of 'manipulation' in publications' abstracts, titles, and keywords, including any publication that used the terms 'misinformation', 'disinformation', 'propaganda', 'fake news', 'rumor'. We also searched for the term 'skeptical', which is commonly applied when discussing information about climate change in similar studies [4]. See Supplementary Note SN1 for the complete search string.

We tested several search term combinations, but the one chosen ensured the highest recall. After testing, we deliberately refrained from searching for specific platform names, such as Twitter and YouTube, as we found that it skewed the search results by systematically overlooking lesser-known platforms. We also decided not to consider gray literature, such as non-peer-reviewed conference abstracts or presentations, because articles that have been through rigorous review are more likely to provide complete methodology information, more refined analysis, and more transportable statistics.

Having searched the databases, we performed a supplementary check for any missed but relevant references, following an approach adopted by similar studies [27]. For this, we consulted the reference lists of two relevant review articles [2,4]. The lead author screened each referenced publication in the mentioned reviews and selected for further screening all those whose title, abstract, or keywords contained the relevant search terms used to collect publications from the two databases. This added 43 additional publications and left us with 294 publications in total, as presented in a PRISMA flowchart (Figure 1).
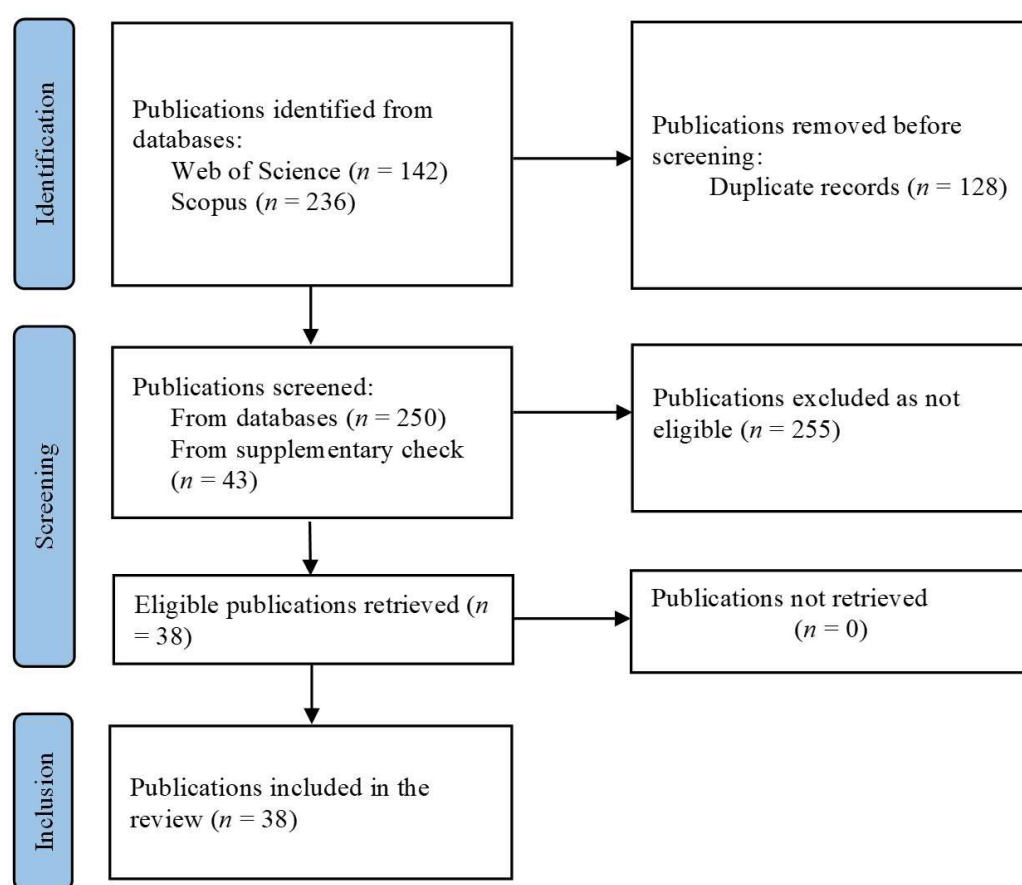

Figure 1. The flow of the publications through the stages of the systematic review.

Supplementary Table S1 presents our codebook that we developed to assess the eligibility of the collected publications, so to make sure a publication focused on manipulation, platforms, and climate change (Supplementary Note SN2 defines each eligibility criterion). Two authors and a research assistant read the titles, abstracts, and keywords of the 293 publications to affirm their eligibility. To achieve an optimum level of reliability, three coders ran a pilot test in pairs. The intercoder reliability for eligibility criteria based on a random sample of 146 publications showed an agreement above 0.6 (see Supplementary Table S3 for Krippendorff's α measures). Disagreements were discussed in the group and resolved [20]. Some publications contained all search terms but did not consider the manipulation of climate change information as an object of study; others were not empirical or did not focus

on social media platforms. In total, 38 publications met our eligibility criteria, all of which could be retrieved fully and, thus, were selected for the main stage of systematic analysis.

Our codebook for the full publication coding was drawn from previous studies of information manipulation on social media [28,29]. We conducted a pilot coding exercise: the three coders compared their coding experiences and adopted the final coding template. All the publications were coded twice. The coders compared their article coding and resolved any discrepancies through conversation.

To address the first research question concerning the progress over time of research on the spread of climate change misinformation on social media, we turned to automatic analysis tools, including *bibliometrix* [30] and a custom script for R. We then summarized the dataset with manual coding, identifying the methods used in the publications. If a publication relied on several methods, both of them were coded. We then moved to research questions two, three, and four, which focus on the sources, channels, and factors that facilitate the spread of manipulative information regarding climate change on social media, as well as the interventions proposed.

5. Results

We have grouped the results into four sets based on the four research questions: the evolution and state of the art of research into manipulative information about climate change spreading on social media; the sources and specific communication channels involved in disseminating such information; the factors exacerbating this dissemination; and proposed interventions to address this problem.

5.1. State of the Art

Our review confirms a sizeable increase in interest in the topic of online manipulation related to climate change. Since 2015, the number of publications focusing on this issue has increased approximately five-fold in absolute terms, as well as in proportion to all scientific publications focusing on climate issues (Figure 2).

However, the geographic focus of this rapidly growing body of research remains highly Western-centric. In particular, our (English language) literature sample is heavily dominated by authors based in the United States and the United Kingdom (Figure 3). Confirming and extending the findings of previous reviews in a systematic manner [4], we found that a lot of the research is focused on the ideological debates in the US. For instance, Moernaut et al. [31] studied how ideological polarization influences people's belief in climate change conspiracies. They found that one side used problematic discursive strategies to delegitimize the other side 'as irrational, immoral or unnatural'. This helped to aggravate the polarization between climate change 'believers' and 'skeptics'.

We found that content analysis is the most common method used to research manipulative information about climate change on social media, with relatively few eligible studies conducting experiments or surveys (Figure 4). This means that most publications that proposed a policy or a solution to the problem of the spread of manipulative information about climate change did not test these interventions. This shows that research into climate change manipulation could benefit from a more intensive application of computational content analysis and network analysis. We also found that the articles we analyzed were published in a diversity of venues, and none of them dominated the sample.
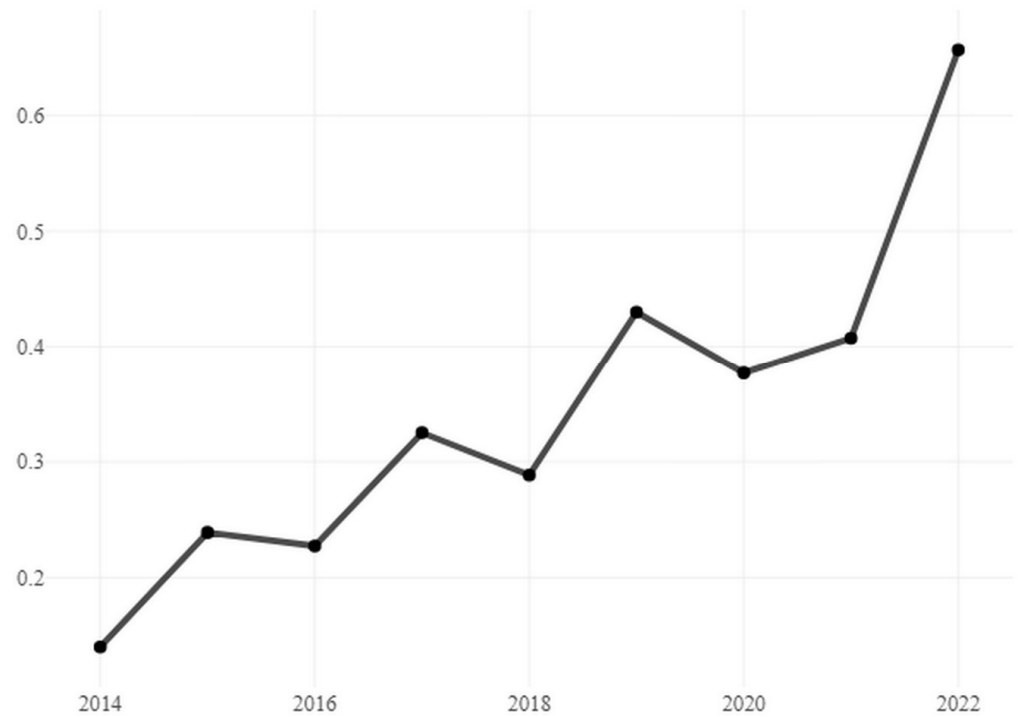
Figure 2. The temporal trends in the eligible publications. Note: n = 38 publications per 1000 eligible publications issued in the same year and containing 'climate' in their title, based on a Web of Science database search.
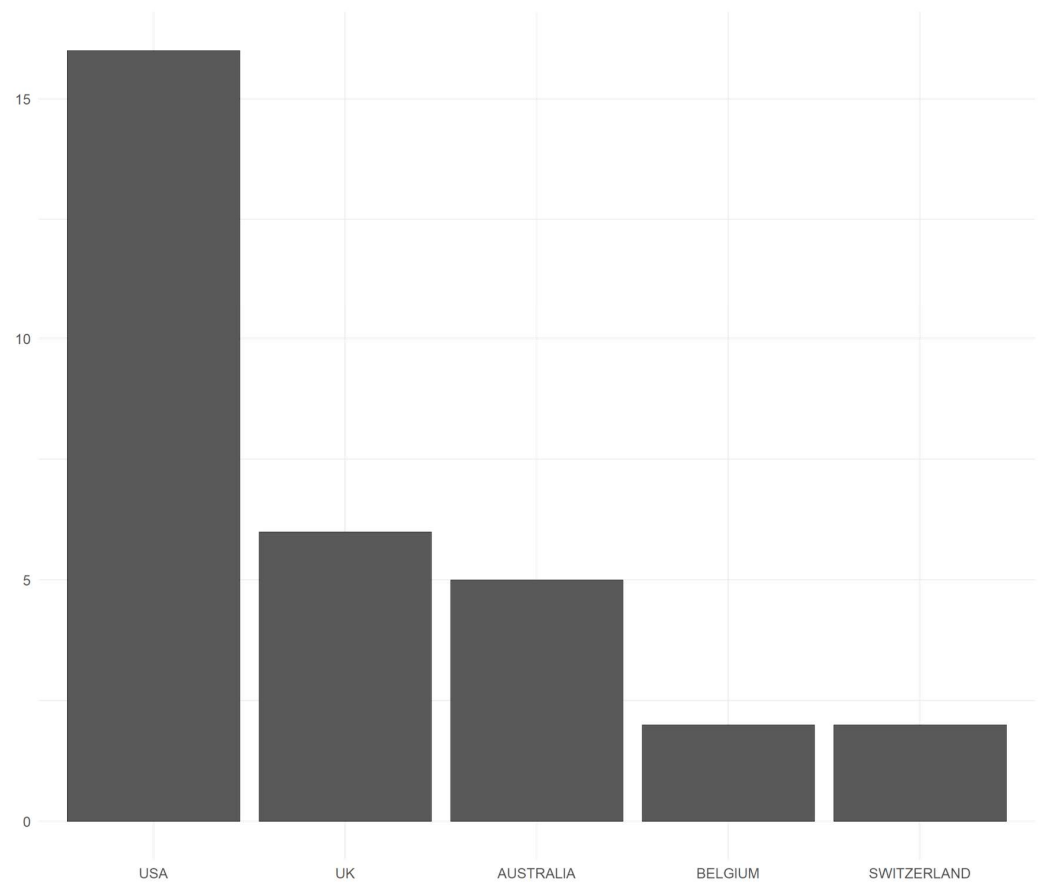

Figure 3. The country of affiliation for the first authors of the eligible publications. Note: n = 38 publications.
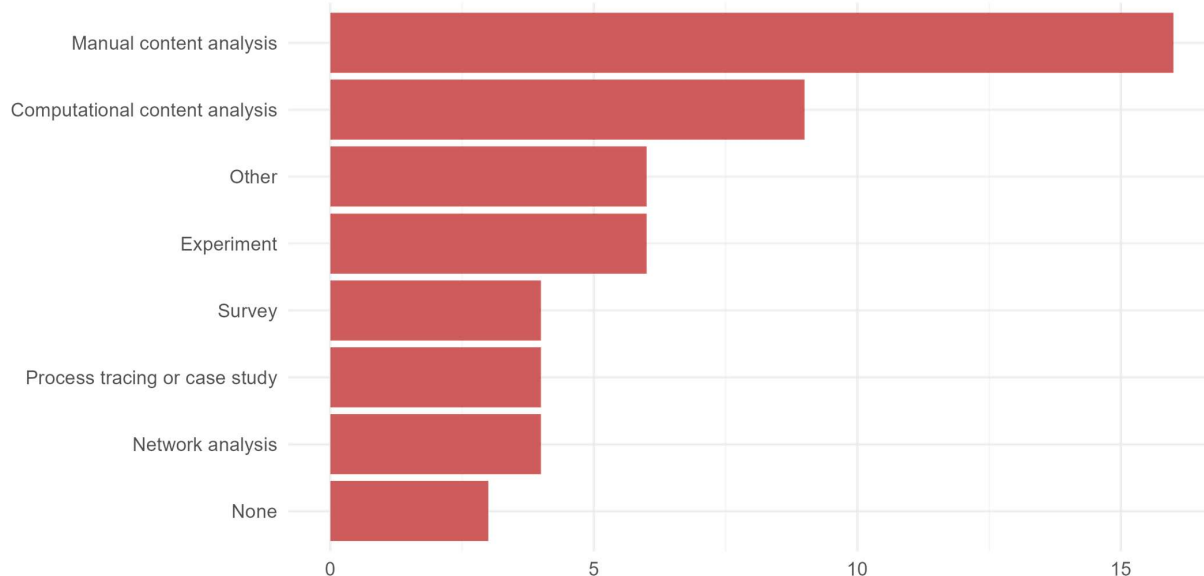
Figure 4. The methods used by the analyzed publications. Note: *n* = 38 publications. 'Other' refers to any method not listed in the figure, such as interviews and review studies—see details in Supplementary Table S1.

5.2. Sources and Channels of Manipulative Information About Climate Change

We found that some crucial sources of manipulative information about climate change are under-studied by researchers focusing on social media. Platform audiences sharing manipulative information about climate change, intentionally or not, are the major focus of these publications (Figure 5). At the same time, very few studies extensively analyzed such important sources of social media content as industry or political entities, e.g., [32,33]. These sources have previously been shown to be behind major campaigns covertly or openly propagating climate denial. For example, Supran and Oreskes found that ExxonMobil's public climate change messaging mimicked "tobacco industry propaganda" [34]. We review this finding in the Discussion section. See Table 1 for an overview of the common manipulative narratives we identified.
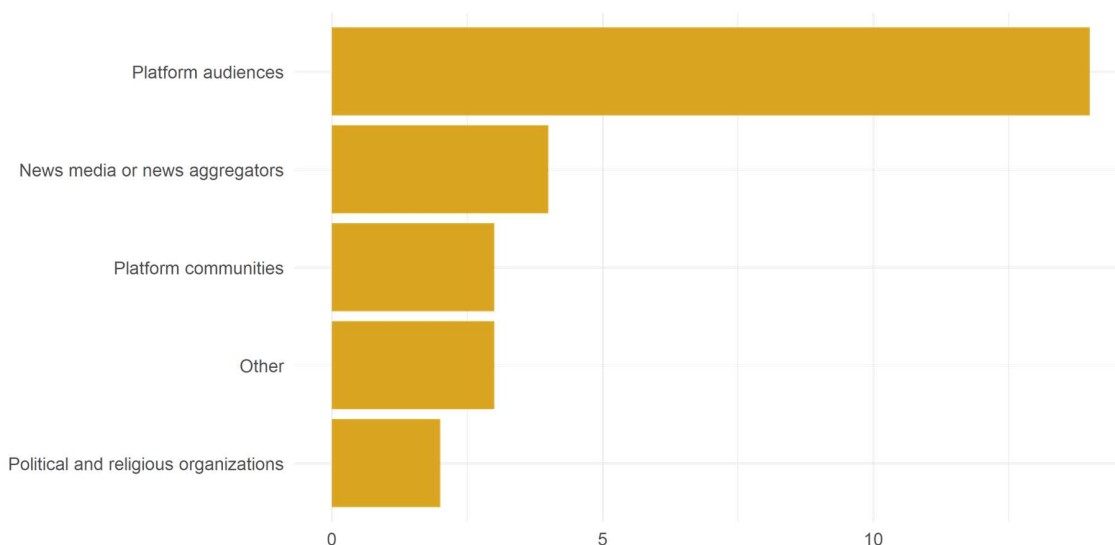

Figure 5. The sources of manipulation studied. Note: *n* = 26 publications that identified or proposed the source of manipulation. The category 'Platform communities' refers to defined or organized units

on a platform, such as groups or pages, while 'Platform audiences' refers to broader and undefined cohorts of users. 'Other' refers to any source that is not listed in the figure but is found in the publications, such as automated accounts, memes, or search engines.

Table 1. Examples of manipulative climate change narratives.

Source	Narratives
	Social Media Platform Users
Twitter communities	Global warming is a myth; climate activism is ecofascism; climate change is not man-made; climate science is a conspiracy favoring the growth of governments; renewable energy is a misuse of taxpayers' money and an inappropriate manipulation of the market; climate science is merely sheep's clothing for the wolf of taxation; tens of thousands of commercial airliners a day are deliberately spraying some kind of mixture of toxic chemicals that influences the environment; climate change is just a natural cycle.
Facebook communities/friends	Global warming is a myth; climate scientists cherry-pick their data.
Instagram accounts	CO_2 is plant food and is good for plants.
	Other Sources
US junk news outlets, e.g., Breitbart, InfoWars, and Natural News	Global warming is a myth; global warming causes global cooling.
Corporate and philanthropic entities, as well as political and religious organizations	Global warming is a myth; climate alarmism.
Contrarian/fake scientists (e.g., Blair Fine)	Global warming is a hoax.
Google, Bing, and Yahoo search webpages	Climate change positively affects agriculture.
YouTube content by professional media organizations, e.g., The Weather Channel, The Onion, ABC News' Good Morning America	'Scientists, the public, celebrities, and the media have accepted the conspiracy that climate change is manufactured'.

We also found that the most common channel for the dissemination of manipulated information examined in the publications was text-based social media posts appearing on older types of platforms—Twitter and Facebook. Visuals-focused channels like Instagram, TikTok, and YouTube received less attention, despite these latter platforms occupying a prominent place in the media diet of audiences [5]. That being said, about a third of the analyzed publications did not specify the channel they examined.

5.3. Factors Exacerbating Manipulation Dissemination

Our analysis shows that the literature emphasizes the personal traits, pre-existing beliefs, and ideologies of consumers of information as variables that are more likely to exacerbate the diffusion of manipulative information about climate change. Hence, the literature focuses on what Chadwick and Stanyer [12] describe as the attributes and actions of the deceived and the role of their beliefs in their consequential attitudes and behavior. In particular, the publications we analyzed show that right-wing [35] or radical political ideology [36,37], trust in science [38], belief in a conspiracy [39], and inclination towards specific emotional reactions [32,40] can prompt individuals to share or engage with manipulated information about climate change. The scope of the analyzed literature is quite broad, which means we had to group variables into wider categories to create a summary (Figure 6).
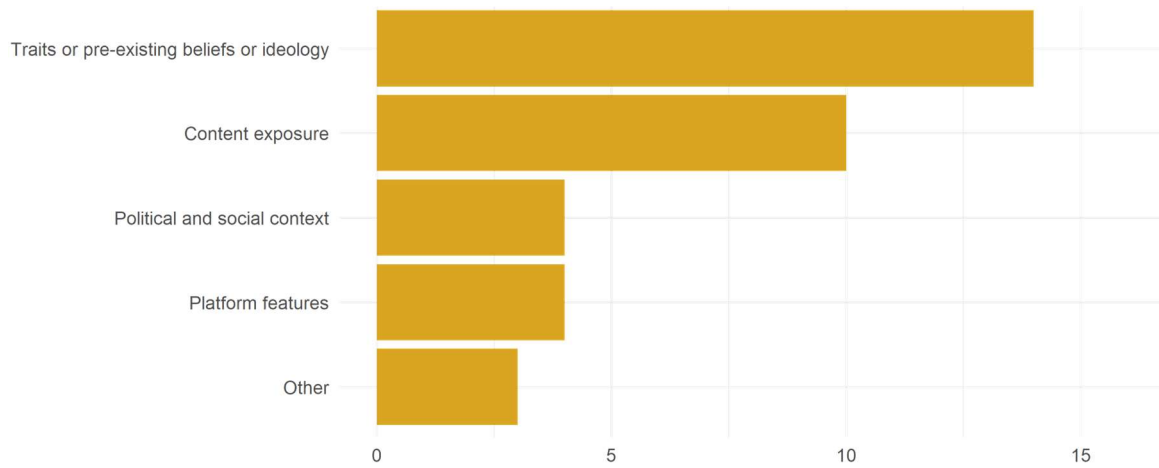
Figure 6. The variables exacerbating the diffusion of manipulative information about climate change. Note: *n* = 21; we excluded eligible studies with no identifiable variables. 'Other' refers to any variables that are not listed in the figure but are discussed in the analyzed publications, such as demographics or general media use patterns.

Content exposure also featured highly on the list of exacerbating variables. This refers to users' exposure to climate change content from *all* types of sources, including right-wing or fact-checking organizations, activists, and ordinary individuals discussing a climate disaster [36,41,42]. However, we know less about content exposure effects as the studies tended to focus instead on a broader range of methods to study traits, beliefs, and ideology (Figure 7).
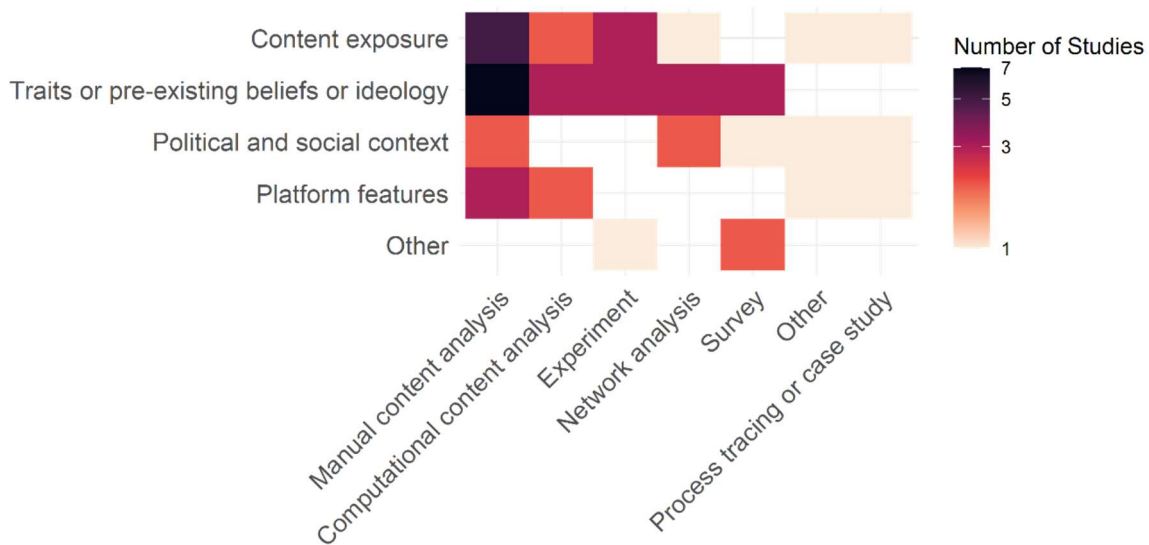

Figure 7. The distribution of variables exacerbating the diffusion of manipulative information about climate change over different combinations of methods. Notes: *n* = 21; we excluded eligible studies with no identifiable variables; if one publication reported several variables or used several methods, we counted them separately.

5.4. Proposed Interventions

The most commonly proposed interventions to address the problem of the spread and influence of manipulative information about climate change include information literacy (47%), corrective information campaigns (26%), and content/account moderation (26%) (Table 2). Across the 19 publications that proposed any interventions, corrective information campaigns and information literacy were the most common suggestions. For example,

Vraga et al. [43] used an experimental design on a national sample of 1005 participants in total to test how two types of corrective information, logic-focused (describing the rhetorical flaw of oversimplification in a problematic message) and fact-focused (focusing on scientific facts) information corrections, affect the perception of manipulative information by Instagram users. Fact-focused corrections countered manipulative information by providing the recipients with accurate information, while logic-focused corrections commonly highlighted the rhetorical flaw underpinning manipulations. According to the authors, both types of corrections helped reduce audiences' 'misperceptions' regarding CO_2 emissions, partly by decreasing the credibility of the original posts containing misinformation [43].

Table 2. Interventions proposed.

Interventions	Number of Publications	Number of Publications That Tested an Intervention	Number of Publications Where Intervention Was Not Rejected After a Test
Specific			
Information literacy	9	3	2
Corrective information campaigns	5	4	3
Content/account moderation	5	1	1
Labeling	4	1	1
Security/verification	2		
Broad or Other	12	2	2

Note: n = 19 publications that proposed any intervention. For examples and references, see the Proposed Interventions section.

We summarize the literature advocating for interventions targeting specific types of variables in Figure 8. The literature shows that corrective information has the potential to tackle manipulation exacerbated by personal traits, beliefs, or ideology. Information literacy campaigns can also influence the latter variables; such campaigns are also potentially useful in addressing political and social contextual factors contributing to the spread of manipulation.
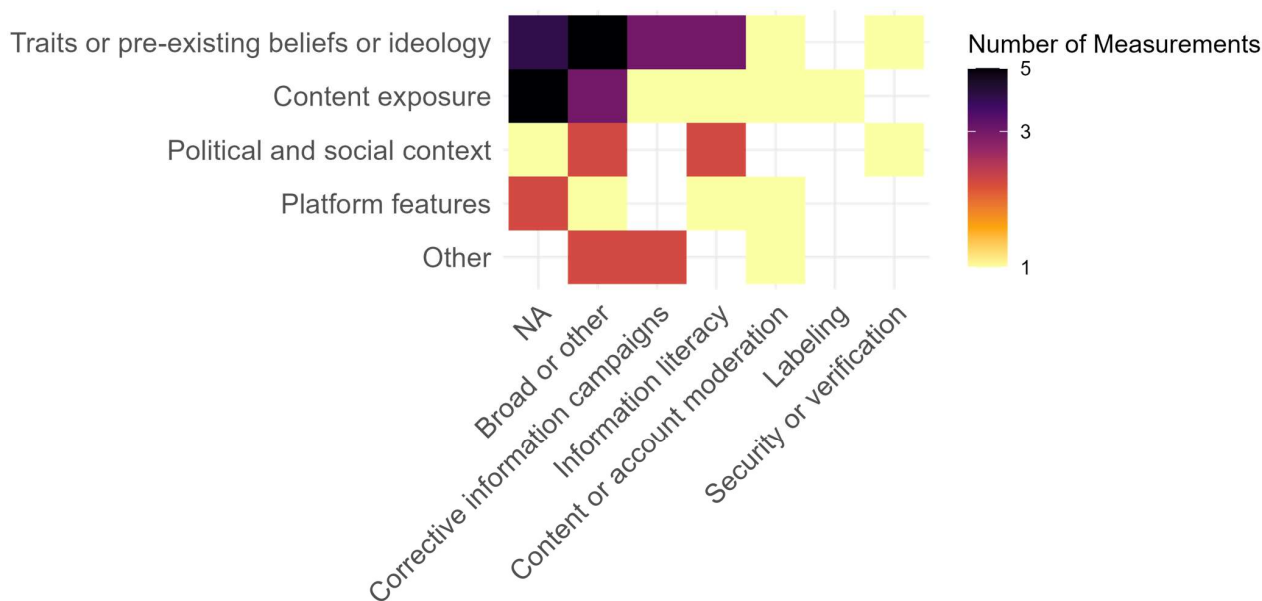

Figure 8. The distribution of variables exacerbating the diffusion of manipulative information about climate change over different combinations of interventions. Notes: n = 21; we excluded eligible studies with no identifiable variables; if one publication reported several variables or proposed several interventions, we counted them separately.

Figure 9 shows how the proposed interventions depend on the format of the studied manipulation: content or account moderation seems to be the most promising intervention if manipulative information is presented in an audio–visual format. At the same time, information literacy campaigns can address manipulative content presented in a textual or visual format. For instance, Anderson and Becker [36] suggested adding humor and sarcasm factors to YouTube video content related to climate change issues to engage more audiences who have a low interest in this field. Twitter and YouTube were the platforms on which the studies proposing an intervention focused, and roughly the same types of interventions were recommended for both, despite multiple differences in affordances and design (Figure 10). In another study, Buchanan et al. [44] advocated using content moderation by removing potential manipulation with the help of an algorithmic approach. It is important to highlight that the majority of the reviewed studies did not test the interventions they proposed.

Half of the publications (50%) analyzed did not propose any intervention, or proposed interventions that were too broad. For example, Sanford et al. [45] suggested that scientists communicating climate change-related information 'need to deepen their understanding of how landmark, science-based reports are communicated and discussed on social media' without providing specific suggestions. Williams et al. [6] advocated for platforms to create a better environment with diverse discussions for 'mixed-attitude communities' to address a 'stabilising effect by reinforcing existing views' from echo chambers. These are important suggestions that, however, do not offer specific recommendations that platform companies or regulators can implement. Overall, to date, much of the research does not offer or evaluate specific measures for redressing digital manipulative information about climate change.

Those few publications in our sample that reported the causal evidence for the relevant interventions they proposed are summarized in Figure 11. We relied on a list of causal inference techniques to determine whether a publication reported causal evidence derived from a causal inference technique commonly considered in similar systematic literature review methodologies (see an example in Lorenz-Spreen et al. [27], Figure 7). We did not pursue a traditional meta-analysis design as the sub-sample of causality-reporting publications was too low. This summary highlights the fact that interventions involving corrective content and priming of critical thinking can reduce the misperception of information about climate change across platforms such as Facebook, Twitter, and Instagram. In particular, priming critical thinking seems to have a promising effect on reducing the credibility and spread of manipulative content related to climate change [46].

Figure 11 also shows that the effectiveness of specific corrective strategies is contextual and depends on heterogeneous factors such as the platform, the time of placing corrections [43], audiences' pre-existing misperceptions of climate change [47], and political ideology [48]. For example, logic-focused corrective content, e.g., refuting rhetorical and logical flaws in the original post, helped to reduce audiences' misperceptions 'regardless of the placement before or after the misinformation' on Instagram [43]. At the same time, fact-focused corrective content only worked when it was placed after misinformation. In another study focusing on Twitter [47], the effects of logic-based and humor-based corrections were mediated by audiences' pre-existing attitudes toward climate change. In addition, these two intervention strategies were more effective if the issue in question was health-related rather than related to climate change misinformation. A study focusing on political ideology found that corrective comments have the potential effect of reducing misperceptions among people with consistent liberal beliefs on Facebook [48]. However, the authors emphasized the importance of collaborative comments involving diverse stake-

holders to counter misinformation, as collaboration is a promising type of intervention regardless of political orientation, according to the authors.
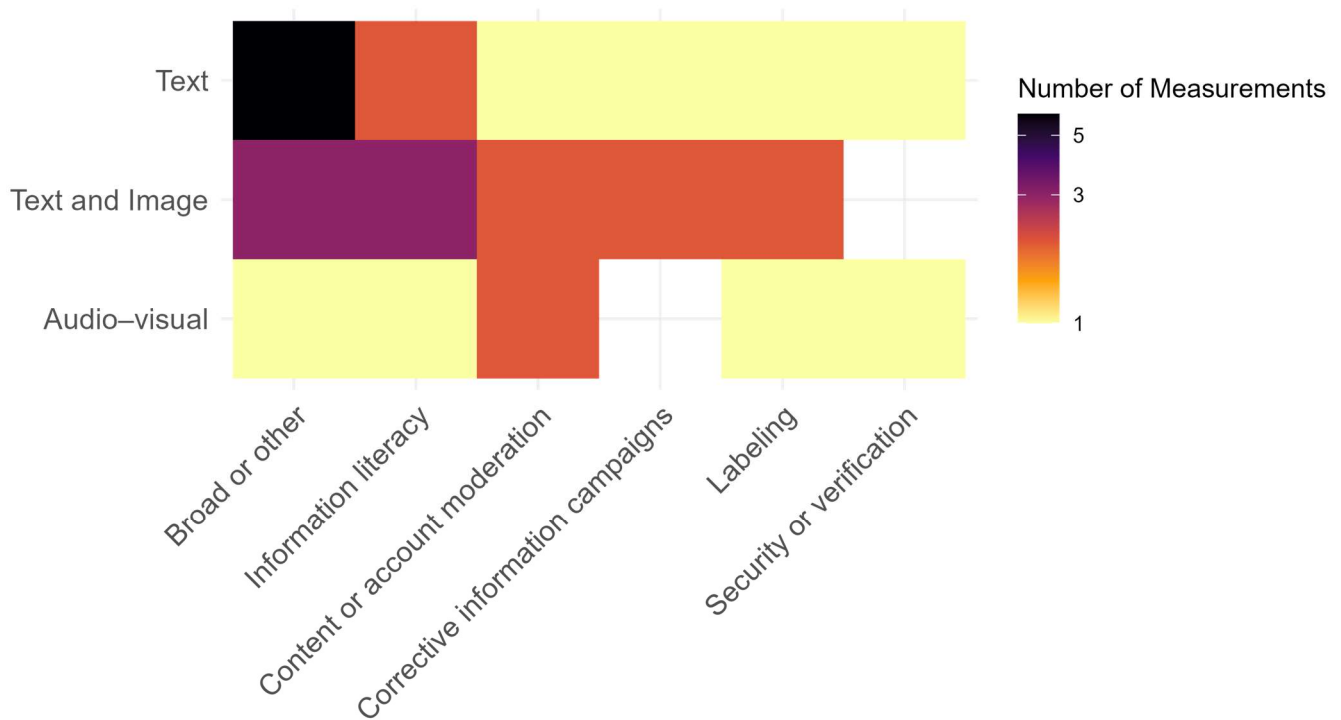

Figure 9. The distribution of manipulation formats over different combinations of proposed interventions. Notes: *n* = 19 publications that proposed any intervention; we excluded eligible studies with no identifiable variables; if one publication reported several formats or proposed several interventions, we counted them separately.
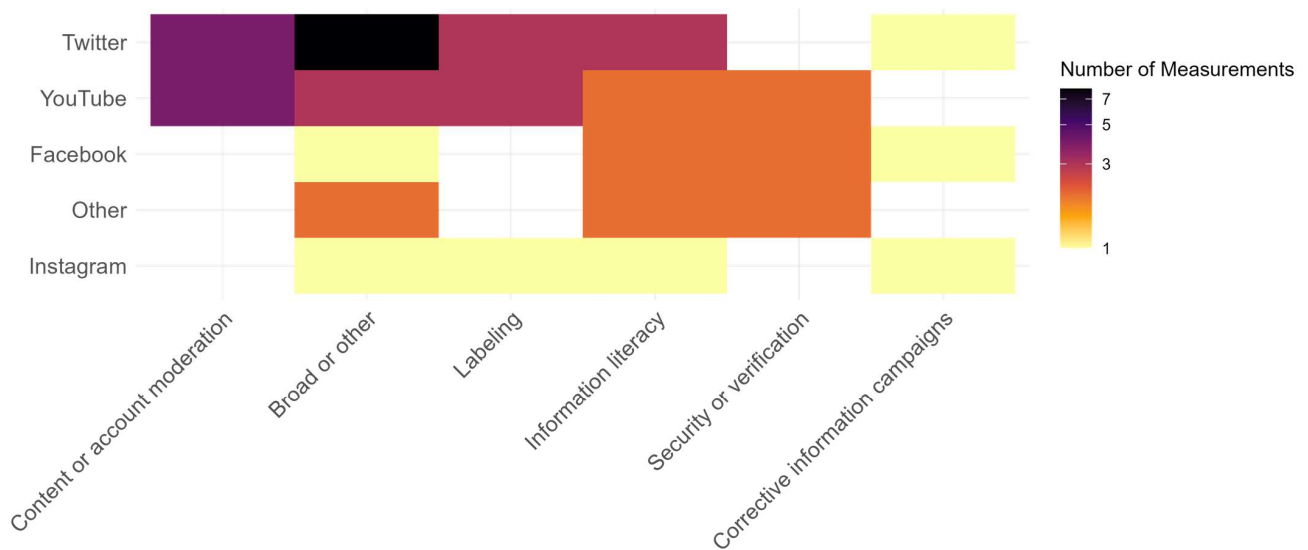

Figure 10. The distribution of platform types over different combinations of proposed interventions. Notes: *n* = 19 publications that proposed any intervention; we excluded eligible studies with no identifiable variables; if one publication reported several platforms or proposed several interventions, we counted them separately.
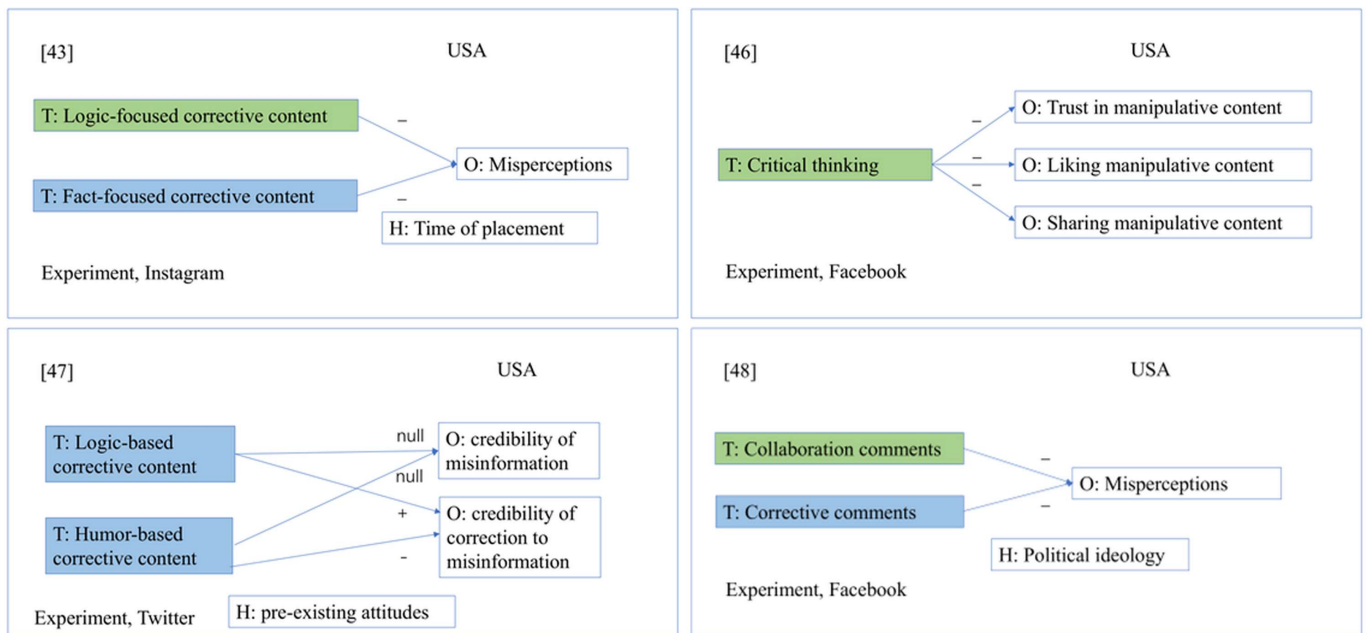
Figure 11. The causal evidence summary. Notes: T: treatment; O: outcome; H: sources of effect heterogeneity or moderators; +: positive effect; −: negative effect; green: effective/beneficial interventions; blue: measures open to interpretation. Sources: [43,46–48].

6. Discussion

To understand the information aspect of climate denial, a great deal of work must be done to analyze how problematic content spreads on social media, a key source of information about climate change. One aspect makes the misleading content about climate change stand out in an applied context compared to other domains of misinformation: such content is often propagated by established and well-known entities with an economic interest in certain perceptions of climate change, along with political and social radical forces. The former are often interested in a rather single-stranded agenda of profiteering, either despite or through climate-related policies related to such domains as fossil fuel and air pollution. These entities emerge as sources of manipulation because they might confuse the debates and make them more blurred, creating uncertainty about scientific facts. Hence, we could not simply rely on 'misinformation', 'disinformation', or 'climate denial' as the only concepts that summarize the problem. Instead, we have extended our review to include all such information and possible elements of climate change communication under the broader umbrella of manipulation.

The literature directs us towards a focus on long-term solutions, such as corrective information campaigns or information literacy promotion, to reduce the 'misperception' of climate change information. This means that social media audiences should be warned about the lies and manipulation they might encounter; they should also be given a chance to learn how to avoid them by using online media more effectively and in a more literate way. Our study highlights media literacy and corrective information as interventions that can reduce the misperception of information about climate change. These findings echo other systematic reviews on solutions to the general problem of misinformation on social media [25,28]. However, our study is the first one to emphasize the importance of these interventions in the literature concerning climate change belief manipulation based on a rigorous review of a relatively large body of literature.

Moreover, we found that relatively few publications suggested account moderation or suspension as an intervention—an approach with effects that have been uncertain in other studies. In addition, security or verification-linked interventions that would involve

additional user verification or de-anonymization policies on a platform were only suggested in two papers. There seems to be insufficient attention towards this type of intervention. One area for future research could be to investigate which types of interventions are generalizable and which ones are too context-specific to be applied in different settings.

We observed that many of the analyzed publications did not clearly specify some of the important elements of their research design or results, such as the exact source or format of manipulation they analyzed. Most publications also did not test the interventions they proposed, which reduces the reliability of the results. Hence, we urge the authors of publications proposing solutions and interventions to mitigate the spread and impact of climate change manipulation to consider specific rather than broader recommendations. Experimental or quasi-experimental design is emerging as a common way to reliably test some design interventions such as labeling, corrective information campaigns, and security/verification (examples from health communication [28] and politics [49] can provide the way forward), while the longitudinal designs used in education research would be required to test information literacy campaign effectiveness [50]. By addressing this design and reporting issue, studies into climate change belief manipulation can help us learn more about mitigating its consequences.

The large commercial and political forces involved in manipulation feature infrequently in the publications we analyzed. Indeed, we might know something about the attributes and actions of the recipients—the deceived, but less about the senders—the deceptive entities [12], specifically those entities involved in large-scale coordinated campaigns of climate information distortion on social media. This is important because such entities as oil and gas firms regularly attempt to manipulate their contribution to global warming through greenhouse gases [51].

This finding differs from earlier reviews that clearly emphasize substantial research into how, as Treen and colleagues suggested, 'corporate and philanthropic actors with a vested interest provide funding to a range of actors who produce climate change misinformation' [4]. This difference might arise due to the changes in how manipulative information is communicated on social media compared to the web in general (the prime focus of Treen et al.) or pre-social media era communication that could be openly attributed to multinational corporations [52]. Indeed, it is more difficult to attribute manipulative information that spreads on social media due to the anonymity of platforms, and the problem of attribution is one of the key issues in misinformation research [3,53]. Hence, social media research often resorts to attributing misinformation to platform users without specifying who might be behind a manipulation campaign.

The results are highly context-dependent. We found less evidence concerning climate change content on video- and image-focused platforms. Evidence about these platforms is important because their audiences have been growing rapidly in recent years. YouTube, for example, was the most visited website after Google globally as of 2023 [54]. Our review did not put an emphasis on any specific platform when selecting publications, and previous research observed the same imbalance in platform focus across related domains. Content produced on platforms such as Twitter and Facebook may be studied more extensively simply because this content could have historically been more accessible for research purposes [55]. Some companies, like the owners of Meta and TikTok, currently offer mandated access for researchers, but this approach raises questions about the independence and reproducibility of the research findings. Nevertheless, our findings do not necessarily mean that researchers are not interested in other platforms.

Finally, we found that researchers have used multiple research methods, such as surveys, interviews, and data science, to answer some of these important questions. Neverthe-

less, the potential of methods that rely on large quantities of data seems to be underexplored in the body of literature.

7. Conclusions

We have found that research into the spread of manipulative information about climate change on social media is rather fragmented, with many country-based or platform-based case studies. Taking a bird's eye view of this research, we note a continued skew towards social media channels that are less widely used for climate change information manipulation. We also observe that the proposed interventions or policy implications remain rather general, while the research that proposes these interventions is mostly focused on the US. It might be hard to carry lessons from the US context over into other contexts. US firms dominate the market of social media platforms. However, the majority of their audiences are based elsewhere. We also observe a huge skew towards research based on text, whereas images and video are used far more widely. This raises the question of a major realignment in the research that would address how climate-relevant content is produced and consumed beyond a few frequently studied countries, and how multimodal content can be analyzed more efficiently. Hence, a theoretical synthesis is required for the more complex environment that has emerged both politically and in terms of social media usage.

In the future, automated methods are bound to become more central to this research. Our research informs these methods by directing them toward the most high-impact interventions. Perhaps more importantly, it can be envisioned that a systematic link could be attempted between findings and interventions, since automated methods allow for the examination of the feedback loops between online climate information and manipulation and their effects. In this respect, social scientists are now competing with the private sector and its marketing techniques, which are able to use tools to shape public understanding of climate change, and the border between marketing and manipulation is becoming blurred.

This study is the first systematic review specifically focusing on the spread of manipulative information about climate change on social media. Future studies can expand our review in at least three ways. First, it would be helpful to analyze manipulative information about climate change in a variety of contexts, expanding our study to other countries through the inclusion of non-English literature, as well as non-social media contexts, such as gaming chats, messaging platforms, and AI conversational agents such as ChatGPT.

Second, relatively few of the studies that expanded on the spread of manipulation tested proposed interventions in relation to climate change information on social media. One way of building more extensive evidence would be comparing the effects across the studies that focused on other problematic aspects of communicating about climate change, such as climate alarmism and related phenomena.

Third, future research should improve upon the limitations of the literature inclusion in this study. It is possible that some studies were excluded from the systematic review even though we undertook an extensive search that included two large social science databases and numerous search terms. For example, we could sample more eligible publications from empirical studies that cite the publications we analyzed and expand the platform search criteria to include additional social media, such as YouTube and TikTok. Still, with our relatively broad search strategy, we had to find a boundary where we would stop our selection. In the meantime, this study should provide an important guide to and outlook on the state of the rapidly expanding field of online manipulation of climate change belief.

References

1. Biddlestone, M.; Azevedo, F.; van der Linden, S. Climate of Conspiracy: A Meta-Analysis of the Consequences of Belief in Conspiracy Theories about Climate Change. *Curr. Opin. Psychol.* **2022**, *46*, 101390. [CrossRef] [PubMed]

2. Rode, J.B.; Dent, A.L.; Benedict, C.N.; Brosnahan, D.B.; Martinez, R.L.; Ditto, P.H. Influencing Climate Change Attitudes in the United States: A Systematic Review and Meta-Analysis. *J. Environ. Psychol.* **2021**, *76*, 101623. [CrossRef]

3. Howard, P.N. *Lie Machines: How to Save Democracy from Troll Armies, Deceitful Robots, Junk News Operations, and Political Operatives*; Yale University Press: New Haven, CT, USA; London, UK, 2020.

4. Treen, K.M.; Williams, H.T.P.; O'Neill, S.J. Online Misinformation about Climate Change. *WIREs Clim. Change* **2020**, *11*, e665. [CrossRef]

5. Ejaz, W.; Mukherjee, M.; Fletcher, R.; Nielsen, R.K. *How We Follow Climate Change: Climate News Use and Attitudes in Eight Countries*; University of Oxford: Oxford, UK, 2022.

6. Williams, H.T.P.; McMurray, J.R.; Kurz, T.; Hugo Lambert, F. Network Analysis Reveals Open Forums and Echo Chambers in Social Media Discussions of Climate Change. *Glob. Environ. Change* **2015**, *32*, 126–138. [CrossRef]

7. Björnberg, K.E.; Karlsson, M.; Gilek, M.; Hansson, S.O. Climate and Environmental Science Denial: A Review of the Scientific Literature Published in 1990–2015. *J. Clean. Prod.* **2017**, *167*, 229–241. [CrossRef]

8. Pearce, W.; Niederer, S.; Özkula, S.M.; Sánchez Querubín, N. The Social Media Life of Climate Change: Platforms, Publics, and Future Imaginaries. *WIREs Clim. Change* **2019**, *10*, e569. [CrossRef]

9. Page, M.J.; McKenzie, J.E.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Shamseer, L.; Tetzlaff, J.M.; Akl, E.A.; Brennan, S.E.; et al. The PRISMA 2020 Statement: An Updated Guideline for Reporting Systematic Reviews. *Syst. Rev.* **2021**, *10*, 89. [CrossRef] [PubMed]

10. Normand, M.P. Science, Skepticism, and Applied Behavior Analysis. *Behav. Anal. Pr.* **2008**, *1*, 42–49. [CrossRef]

11. O'Neill, S.J.; Boykoff, M. Climate Denier, Skeptic, or Contrarian? *Proc. Natl. Acad. Sci. USA* **2010**, *107*, E151. [CrossRef]

12. Chadwick, A.; Stanyer, J. Deception as a Bridging Concept in the Study of Disinformation, Misinformation, and Misperceptions: Toward a Holistic Framework. *Commun. Theory* **2022**, *32*, 1–24. [CrossRef]

13. Benkler, Y.; Faris, R.; Roberts, H. *Network Propaganda: Manipulation, Disinformation, and Radicalization in American Politics*; Oxford University Press: Oxford, UK, 2018; ISBN 978-0-19-092363-1.

14. Klinenberg, E.; Araos, M.; Koslov, L. Sociology and the Climate Crisis. *Annu. Rev. Sociol.* **2020**, *46*, 649–669. [CrossRef]

15. Bauer, M.W.; Allum, N.; Miller, S. What Can We Learn from 25 Years of PUS Survey Research? Liberating and Expanding the Agenda. *Public Underst. Sci.* **2007**, *16*, 79–95. [CrossRef]

16. Hornsey, M.J.; Harris, E.A.; Bain, P.G.; Fielding, K.S. Meta-Analyses of the Determinants and Outcomes of Belief in Climate Change. *Nat. Clim Change* **2016**, *6*, 622–626. [CrossRef]

17. Boykoff, M.T. *Who Speaks for the Climate?: Making Sense of Media Reporting on Climate Change*; Cambridge University Press: Cambridge, UK, 2011; ISBN 978-0-521-13305-0.

18. Ceyhan, G.D.; Saribas, D. Research Trends on Climate Communication in the Post-Truth Era. *Educ. Dev. Psychol.* **2022**, *39*, 5–16. [CrossRef]

19. Schäfer, M.S. Online Communication on Climate Change and Climate Politics: A Literature Review. *WIREs Clim. Change* **2012**, *3*, 527–543. [CrossRef]

20. Siddaway, A.P.; Wood, A.M.; Hedges, L.V. How to Do a Systematic Review: A Best Practice Guide for Conducting and Reporting Narrative Reviews, Meta-Analyses, and Meta-Syntheses. *Annu. Rev. Psychol.* **2019**, *70*, 747–770. [CrossRef] [PubMed]

21. Freelon, D.; Wells, C. Disinformation as Political Communication. *Political Commun.* **2020**, *37*, 145–156. [CrossRef]

22. Douglas, K.M.; Uscinski, J.E.; Sutton, R.M.; Cichocka, A.; Nefes, T.; Ang, C.S.; Deravi, F. Understanding Conspiracy Theories. *Political Psychol.* **2019**, *40*, 3–35. [CrossRef]

23. Abu Arqoub, O.; Abdulateef Elega, A.; Efe Özad, B.; Dwikat, H.; Adedamola Oloyede, F. Mapping the Scholarship of Fake News Research: A Systematic Review. *J. Pract.* **2022**, *16*, 56–86. [CrossRef]

24. Norris, M.; Oppenheim, C. Comparing Alternatives to the Web of Science for Coverage of the Social Sciences' Literature. *J. Informetr.* **2007**, *1*, 161–169. [CrossRef]

25. Bryanov, K.; Vziatysheva, V. Determinants of Individuals' Belief in Fake News: A Scoping Review Determinants of Belief in Fake News. *PLoS ONE* **2021**, *16*, e0253717. [CrossRef] [PubMed]

26. Mahl, D.; Schäfer, M.S.; Zeng, J. Conspiracy Theories in Online Environments: An Interdisciplinary Literature Review and Agenda for Future Research. *New Media Soc.* **2022**, *25*, 1781–1801. [CrossRef]

27. Lorenz-Spreen, P.; Oswald, L.; Lewandowsky, S.; Hertwig, R. A Systematic Review of Worldwide Causal and Correlational Evidence on Digital Media and Democracy. *Nat. Hum. Behav.* **2022**, *7*, 74–101. [CrossRef]

28. Walter, N.; Brooks, J.J.; Saucier, C.J.; Suresh, S. Evaluating the Impact of Attempts to Correct Health Misinformation on Social Media: A Meta-Analysis. *Health Commun.* **2021**, *36*, 1776–1784. [CrossRef] [PubMed]

29. Yadav, K. *Platform Interventions: How Social Media Counters Influence Operations*; Carnegie Endowment for International Peace: Washington, DC, USA, 2021.

30. Aria, M.; Cuccurullo, C. Bibliometrix: An R-Tool for Comprehensive Science Mapping Analysis. *J. Informetr.* **2017**, *11*, 959–975. [CrossRef]

31. Moernaut, R.; Mast, J.; Temmerman, M.; Broersma, M. Hot Weather, Hot Topic. Polarization and Sceptical Framing in the Climate Debate on Twitter. *Inf. Commun. Soc.* **2022**, *25*, 1047–1066. [CrossRef]

32. Eslen-Ziya, H. Humour and Sarcasm: Expressions of Global Warming on Twitter. *Humanit. Soc. Sci. Commun.* **2022**, *9*, 240. [CrossRef]

33. Reed, M. 'This Loopy Idea' an Analysis of UKIP's Social Media Discourse in Relation to Rurality and Climate Change. *Space Polity* **2016**, *20*, 226–241. [CrossRef]

34. Supran, G.; Oreskes, N. Rhetoric and Frame Analysis of ExxonMobil's Climate Change Communications. *One Earth* **2021**, *4*, 696–719. [CrossRef]

35. Cann, T.J.B.; Weaver, I.S.; Williams, H.T.P. Ideological Biases in Social Sharing of Online Information about Climate Change. *PLoS ONE* **2021**, *16*, e0250656. [CrossRef] [PubMed]

36. Anderson, A.A.; Becker, A.B. Not Just Funny after All: Sarcasm as a Catalyst for Public Engagement with Climate Change. *Sci. Commun.* **2018**, *40*, 524–540. [CrossRef]

37. Jacques, P.J.; Knox, C.C. Hurricanes and Hegemony: A Qualitative Analysis of Micro-Level Climate Change Denial Discourses. *Environ. Politics* **2016**, *25*, 831–852. [CrossRef]

38. Diehl, T.; Huber, B.; Gil de Zúñiga, H.; Liu, J. Social Media and Beliefs about Climate Change: A Cross-National Analysis of News Use, Political Ideology, and Trust in Science. *Int. J. Public Opin. Res.* **2021**, *33*, 197–213. [CrossRef]

39. Tingley, D.; Wagner, G. Solar Geoengineering and the Chemtrails Conspiracy on Social Media. *Palgrave Commun.* **2017**, *3*, 12. [CrossRef]

40. Forti, L.R.; de Travassos, M.L.O.; Coronel-Bejarano, D.; Miranda, D.F.; Souza, D.; Sabino, J.; Szabo, J.K. Posts Supporting Anti-Environmental Policy in Brazil Are Shared More on Social Media. *Environ. Manag.* **2022**, *71*, 1188–1198. [CrossRef]

41. Fine, J.C.; Love-Nichols, J. We Are (Not) the Virus: Competing Online Discourses of Human-Environment Interaction in the Era of COVID-19. *Environ. Commun.* **2021**, *17*, 293–312. [CrossRef]

42. Xu, Z.; Atkin, D.J. Framing Climate Change in the 5th Estate: Comparing Online Advocacy and Denial Webpages and Their Engagement. *Electron. News* **2022**, *16*, 84–103. [CrossRef]

43. Vraga, E.K.; Kim, S.C.; Cook, J.; Bode, L. Testing the Effectiveness of Correction Placement and Type on Instagram. *Int. J. Press/Politics* **2020**, *25*, 632–652. [CrossRef]

44. Buchanan, G.; Kelly, R.; Makri, S.; McKay, D. Reading between the Lies: A Classification Scheme of Types of Reply to Misinformation in Public Discussion Threads. In Proceedings of the ACM SIGIR Conference on Human Information Interaction and Retrieval; Association for Computing Machinery, New York, NY, USA, 14 March 2022; pp. 243–253.

45. Sanford, M.; Painter, J.; Yasseri, T.; Lorimer, J. Controversy around Climate Change Reports: A Case Study of Twitter Responses to the 2019 IPCC Report on Land. *Clim. Change* **2021**, *167*, 59. [CrossRef]

46. Lutzke, L.; Drummond, C.; Slovic, P.; Árvai, J. Priming Critical Thinking: Simple Interventions Limit the Influence of Fake News About Climate Change on Facebook. *Glob. Environ. Change* **2019**, *58*, 101964. [CrossRef]

47. Vraga, E.K.; Kim, S.C.; Cook, J. Testing Logic-Based and Humor-Based Corrections for Science, Health, and Political Misinformation on Social Media. *J. Broadcast. Electron. Media* **2019**, *63*, 393–414. [CrossRef]

48. Lawrence, E.K.; Estow, S. Responding to Misinformation about Climate Change. *Appl. Environ. Educ. Commun.* **2017**, *16*, 117–128. [CrossRef]

49. Walter, N.; Cohen, J.; Holbert, R.L.; Morag, Y. Fact-Checking: A Meta-Analysis of What Works and for Whom. *Political Commun.* **2020**, *37*, 350–375. [CrossRef]

50. Smithers, L.G.; Sawyer, A.C.P.; Chittleborough, C.R.; Davies, N.M.; Davey Smith, G.; Lynch, J.W. A Systematic Review and Meta-Analysis of Effects of Early Life Non-Cognitive Skills on Academic, Psychosocial, Cognitive and Health Outcomes. *Nat. Hum. Behav.* **2018**, *2*, 867–880. [CrossRef]

51. Tauschinski, J.; Mooney, A. *How Oil and Gas Companies Disguise Their Methane Emissions*; Financial Times: London, UK, 2024.

52. Schlichting, I. Strategic Framing of Climate Change by Industry Actors: A Meta-Analysis. *Environ. Commun.* **2013**, *7*, 493–511. [CrossRef]

53. Herasimenka, A.; Au, Y.; George, A.; Joynes-Burgess, K.; Knuutila, A.; Bright, P.; Howard, P.N. The Political Economy of Digital Profiteering: Communication Resource Mobilization by Anti-Vaccination Actors. *J. Commun.* **2022**, *73*, 126–137. [CrossRef]

54. Alexa Top Websites | Last Save before It Was Closed. Available online: https://www.expireddomains.net/alexa-top-websites/ (accessed on 14 January 2025).

55. Perriam, J.; Birkbak, A.; Freeman, A. Digital Methods in a Post-API Environment. *Int. J. Soc. Res. Methodol.* **2019**, *23*, 1–14. [CrossRef]