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Climate Misinformation: Communicating Climate Science in an Era of Misinformation

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Abstract

Whereas scientific dissent regarding climate change was once the greatest barrier to climate action, 97 percent of climatologists agree climate change is happening and is human-caused. Now, climate misinformation stands out as a prevalent modern barrier to climate action. Climate misinformation has adverse impacts on public perception of and support for climate science. Mastering climate communication is integral for counteracting climate misinformation and relaying modern climate science comprehensibly to the public and policymakers. This review synthesizes current research surrounding climate misinformation, discusses identified strategies to combat misinformation, and highlights methods for effective climate communication appropriately adapted for an era of climate misinformation. It concludes with a critical analysis of the methods used throughout the literature and provides suggestions to improve the credibility of future research. The review emphasizes that the future of climate communication must remain responsive to climate misinformation tactics because the increasing prevalence of climate change compels disseminators of climate misinformation to adapt their strategies to remain effective.

1. Introduction

Those well-versed in climate policy recognize *Merchants of Doubt* as an eye-opening documentary that reveals numerous similarities between the notorious misinformation campaign of the tobacco industry and that which wreaks havoc upon climate communicators and activists in the 21st century. A quote from a tobacco executive illustrates as much: "Doubt is our product since it is the best means of competing with the 'body of fact' that exists in the minds of the general public. It is also the means of establishing a controversy" (Treen et al., 2020, pp. 8). Consider this in juxtaposition with a finding from Supran and Oreskes (2017, pp. 1): from 1977 to 2014, ExxonMobil acknowledged that climate change is "real and human-caused" in 80 percent of its internal documents but communicated doubt about the climate crisis in 81 percent of its public-facing materials.

Misinformation campaigns like these exacerbate political polarization and decrease public trust in the scientific consensus on climate change, which has effectively delayed climate action for nearly seventy years (Jacques et al., 2008; Treen et al., 2020; *Taking a Global Perspective on Earth's Climate*, n.d.).

The detriment of climate misinformation to climate action necessitate attention to its definition, perpetuators, vehicles of dissemination, impacts, and corrective strategies. Previous review publications on climate misinformation evaluate the current understanding of effective communication strategies in response to climate misinformation. However, there has been no prior attempt to evaluate these strategies in the context of the factors, spreaders, and implications of climate misinformation. Therefore, the goals of this literature review are to discuss published research articles that (a) explain the meaning of the term *climate misinformation*, (b) identify perpetrators of climate misinformation, (c) relay the mechanisms responsible for disseminating climate misinformation, (d) highlight strategies deemed effective for refuting misinformation and communicating climate science, and (e) suggest topics for future research to aid in the deconstruction of climate misinformation. Providing a holistic review of the current research addressing climate misinformation will improve readers' understandings of how the phenomenon has initiated an era of media consumption that is not conducive to climate action.

2. Climate Misinformation: A Poison for Climate Action

The true meaning of *misinformation* as a term used in discussions about climate change is often ambiguous because the contexts in which it is used vary greatly according to the political and ideological perspectives of its user. Only two of the reviewed articles, Treen et al. (2020) and Cook et al. (2018), explicitly defined the term. From a review of one hundred fifty research articles addressing climate misinformation, Treen et al. (2020) described misinformation as information that is inaccurate or misleading, but not necessarily intentionally malicious. Cook et al. (2018, pp. 1) operated using a definition that is similar to that of Treen et al.,- "information initially presented as true that is later found to be false"- but do not consider the intentionality of misinformation. This literature review acknowledges the specificity of the definition for misinformation provided by Treen et al. (2020) but also adopts the definition posed by Cook et al. (2018) since it is nearly identical to the former. However, this review gives special attention to climate misinformation published with the intent of confusing or misleading the public because it is within these efforts that the most debilitating consequences of climate misinformation lie.

Climate misinformation inhibits climate action by catering to individuals' values, belief systems, and lifestyle characteristics to cloud judgment towards important social and political decisions addressing the

climate crisis. The result is climate skepticism, which Wang and Kim (2018, pp. 3) described as "a family of arguments or individuals that reject, dispute, or question the orthodox view of the climate issue." This review identifies climate skeptics as individuals who spread climate misinformation as deniers of climate change, which reduces public concern for the climate crisis and advocacy for climate action. Importantly, the relationship between climate misinformation and climate skepticism is not linear or one-way. Climate skeptics can begin as such and spread climate misinformation, too.

2.1 Factors

Values, belief systems, and lifestyle characteristics are highly interconnected to climate skepticism and an individual's acknowledgment of climate change. Generally, individuals who fall victim to climate misinformation are more likely to be skeptical about anthropogenic climate change and, therefore, less likely to acknowledge its existence (Krosnick et al., 2006). Previous research demonstrates that values, belief systems, and lifestyle characteristics are accurate predictors of individuals' susceptibilities to believing climate misinformation, skepticism toward the existence and causes of climate change, and acknowledgment of the climate crisis. Table 1 summarizes the findings of such research, while the paragraphs that follow discuss the researchers' findings.

Wang and Kim (2018, pp. 4) defined values as "fundamental guiding principles that are more specific and more stable than worldviews." The current review generates a comprehensive list of seven values influential to climate misinformation susceptibility: egalitarianism[1], environmentalism, free-market ideology, hierarchy, individualism, political ideology, and science and technology (S&T) optimism. According to Hornsey and Fielding (2020), high regard for egalitarianism increases one's likelihood of acknowledging climate change, and thus, decreases their susceptibility to climate misinformation. The researchers find a "moral suspicion of powerful corporations" among egalitarians that motivates acknowledgement of and opposition for the damage industry presents to the environment (Hornsey and Fielding, 2020, pp. 10). Wang and Kim (2018) also concluded that there is an inverse relationship between egalitarianism and the susceptibility of deceptive climate rhetoric, but it was a not statistically significant result.

Wang and Kim (2018) found that an increase in environmentalism decreases climate skepticism and susceptibility to climate misinformation because environmentalism fosters an understanding of human connections to nature. In fact, Wang and Kim (2018) deemed environmentalism the strongest determinant for certainty about climate change. Free-market ideology increases one's susceptibility to climate misinformation because it cultivates prioritization for minimal government regulation, even at the

[1] Egalitarianism is a belief in political philosophy that advocates for human equality, particularly in economic, social, and political contexts (Arneson, 2002).

expense of resolving collective-action problems like anthropogenic climate change (Hornsey and Fielding, 2020).

Hierarchy is considered a cultural bias through which individuals favor existing social structures and, therefore, powerful interests like industry and trade. Hierarchical individuals are apprehensive about supporting new ideas, such as climate action, because addressing environmental issues often involves restricting commerce and free trade (Wang and Kim, 2018; Zummo et al., 2021). Given the apparent threat of environmentalism to the success of industry, values for hierarchy increase one's risk of falling victim to misleading climate information (Wang and Kim, 2018; Hornsey and Fielding, 2020).

For reasons similar to those who value hierarchy, individualistic people are more often skeptical of and less likely to acknowledge anthropogenic climate change. Consequently, they are more susceptible to climate misinformation (Hornsey and Fielding, 2020; Wang and Kim, 2018). Individualists believe that supporting environmental action threatens the larger institutions that they often support, including commerce and industry (Wang and Kim, 2018). Hornsey and Fielding (2020, pp. 9) draw the connection between those who value hierarchy and individualists rather clearly: "…people who subscribe to relatively individualistic and hierarchical values are more inclined to value elites and powerful interests, and so by extension are motivated to reject the notion that industry will put the environment at risk."

With regard to political ideology, numerous studies discovered that conservatism exacerbates climate skepticism and susceptibility to climate misinformation (Jacques et al., 2008; Benegal and Scruggs, 2018; Wang and Kim, 2018; Hornsey and Fielding, 2020; Kaiser et al., 2021; Sarathchandra and Haltinner, 2021; Zhou and Shen, 2021; Zia and Todd, 2010; Zummo et al., 2021). Zia and Todd (2010) cite several reasons for disbelief of and/or lack of concern for anthropogenic climate change among conservatives, including that scientists do not have sufficient understanding about climate change, climate change is natural and not human-caused, and that climate change is not a significant concern of the present or future. Jacques et al. (2008, pp. 352) reasons that this trend gained momentum particularly in the 1990s with the launch of a "major counter-movement" against the environmental movement of this decade.

Finally, there exists a weak positive correlation between S&T optimism and susceptibility to climate misinformation (Wang and Kim, 2018). Those who are optimistic about S&T generally believe that S&T resolve more problems than they generate and, similarly, that they provide more positive outcomes for society than negative outcomes. Trust in these two principles render S&T optimists more likely to fall victim to climate misinformation because they feel assured that S&T will resolve climate change. This is associated with reduced concern for and skepticism about climate change. Optimistic sentiments for S&T can be linked to the history of climate denial in Western societies, which was founded upon the notion

that economic successes attributed to S&T advancements should negate any concerns for resolving climate change (Wang and Kim, 2018).

Belief systems are also influential to an individual's susceptibility to climate misinformation because, as Wang and Kim (2018, pp. 4) explained, perceptions affect "interpretation[s] of situations or events." Namely, perceived risk, perceived benefit, negative attitude, trust, religiosity, and confirmation bias all contribute relevant findings to the reviewed literature. Heightened senses of the risks posed by climate change, the benefits offered by climate policy, and negative sentiments in response to climate change all decrease climate skepticism and susceptibility to climate misinformation (Wang and Kim, 2018). They are, in fact, very interconnected variables. For instance, there is an inverse relationship between positive experiences with previous climate policies and the perceived risk of climate change (Niles et al., 2013). Since climate change is viewed as a risk, it reasons that increased perceived benefits of climate action are associated with greater overall concern for climate change and, with it, reduced susceptibility to climate misinformation. Negative sentiments including guilt, anger, and hopelessness toward climate change are especially powerful predictors of support for climate policy (Wang and Kim, 2018).

According to Wang and Kim (2018), trust in climate science is inversely related to climate skepticism and misinformation susceptibility, suggesting that individuals who trust climate science are less likely to interpret climate misinformation as fact. Interestingly, Wang and Kim (2018) also found that decreased trust in climatologists, which has trended since the early 2000s, exists largely among individualists and conservatives. Alternatively, Kellstedt et al. (2008) concluded that increased trust in climate scientists cultivates decreased responsibility and concern for global warming. This rejects the notion that decreased susceptibility to climate misinformation correlates with greater likelihood for climate action. The literature reviewed yields an inconclusive relationship between the influence of trust on susceptibility to climate misinformation.

Stronger religious beliefs generally predict increased susceptibility to skepticism and climate misinformation (Sarathchandra and Haltinner, 2021; Wang and Kim, 2018). This trend may stem from the anthropocentric view of Judeo-Christians that the natural world is "created for human use" (Wang and Kim, 2018, pp. 16). However, religiosity is not a particularly strong predictor of susceptibility to climate misinformation or the acknowledgement of anthropogenic climate change. The literature also cites confirmation bias as a predictor of increased susceptibility to climate misinformation. Confirmation bias increases one's likelihood of falling victim to climate misinformation, especially when the information is presented within existing social networks (Treen et al., 2020; Zhou and Shen, 2021).

Lifestyle characteristics are a particularly intriguing subset of factors influential to climate misinformation susceptibility because they are more objective than values and belief systems. A review of the literature identifies seven noteworthy lifestyle characteristics: age, income, education, experience with extreme weather, gender, social class, and race. Analysis reveals that age is positively correlated with susceptibility to climate misinformation (Wang and Kim, 2018; Hornsey and Fielding, 2020). Wang and Kim (2018) concluded that susceptibility increases with income, while Hornsey and Fielding (2020) found that there is no correlation between income level and one's likelihood of believing climate misinformation. Repeated research is recommended to better understand the influences of income on susceptibility to climate misinformation.

Several researchers support that increased education levels decrease susceptibility to climate misinformation (Chen and Unsworth, 2019; Hornsey and Fielding, 2020; Wang and Kim, 2018; Zia and Todd, 2010). In a study exploring the correlation between education level and the likelihood of acknowledging anthropogenic climate change, Chen and Unsworth (2019) found that individuals with higher levels of acquired education were more likely to acknowledge anthropogenic climate change. This is because higher cognitive complexity warrants multi-perspective thinking that makes climate misinformation easily refutable (Chen and Unsworth, 2019). Sarathchandra and Haltinner (2020) refuted the seemingly robust inverse relationship between education and susceptibility to climate misinformation with their conclusion that education does not have an impact on the chance that an individual believes climate misinformation. Still, Table 1 categorizes education level as having an inverse relationship with an individual's susceptibility to climate misinformation. Sarathchandra and Haltinner (2020) employed a biased experiment design that renders their results unreliable, the details of which are examined in the Discussion of this review.

Hornsey and Fielding (2020) found that, in the aftermath of widespread flooding events, individuals were more likely to acknowledge climate change if they were severely affected by an extreme weather event. However, similar results were not reflected in other experiments, so Table 1 considers the relationship between experience with an extreme weather event and susceptibility to climate change as inconclusive and/or inconsistent.

Researchers also found that gender, social class, and race do not have any observable impact on climate misinformation susceptibility (Hornsey and Fielding, 2020; Wang and Kim, 2018). Although, Sarathchandra and Haltinner (2021) concluded that skeptic males are, with statistical significance, more susceptible to climate misinformation than skeptic females.

	Increases susceptibility	Decreases susceptibility	No effect on susceptibility	Inconclusive and/or inconsistent results
Values				
Egalitarianism				X
Environmentalism		X		
Free-market ideology	X			
Hierarchy	X			
Individualism	X			
Conservative political ideology	X			
Science and technology (S&T) optimism	X			
Belief systems				
Perceived risk		X		
Perceived benefit		X		
Negative attitude		X		
Trust				X
Religiosity	X			
Confirmation bias	X			
Lifestyle characteristics				
Age	X			
Income				X
Education		X		
Extreme weather experience				X
Gender				X
Social class			X	
Race			X	

TABLE 1. Known trends among values, belief systems, and lifestyle characteristics on susceptibility to climate misinformation. It is important to note the evident interconnection between these values, e.g., an individual's belief system may influence their political ideology, both of which affect their susceptibility to climate misinformation. This observation is further explored in the Discussion. (Information compiled from Benegal and Scruggs, 2018; Chen and Unsworth, 2019; Hornsey and Fielding, 2020; Jacques et al., 2008; Kaiser et al., 2021; Sarathchandra and Haltinner, 2021; Treen et al., 2020; Wang and Kim, 2018; Zhou and Shen, 2021; and Zia and Todd, 2010.)

2.2 Spreaders

Disseminators of climate misinformation impede climate action because they perpetuate inaccurate and misleading claims that are detrimental to the public consensus on climate change and trust in climate scientists.

Because humans profess beliefs congruent with their own, those most susceptible to climate misinformation are the most prevalent disseminators of climate misinformation (Connor et al., 2016). Importantly, not all individuals who fall victim to and/or disseminate climate misinformation have malicious intent. This review focuses on those with malicious intent to misinform the public about climate science because it considers them a greater threat to the prevalence of climate misinformation. As Supran and Oreskes (2017) exemplified through ExxonMobil, intentional spreaders of climate misinformation are often motivated to spread falsities because they fear that, if climate change were acknowledged as fact, consequent climate action would negatively impact the individual or the company to which they belong (Hornsey and Fielding, 2020).

Several researchers found that individuals belonging to or funded by fossil fuel, coal, automotive, electric utility, and conservative institutions are the most prominent disseminators of climate misinformation (Treen et al., 2020). According to Farrell (2019), donor-directed philanthropy has also developed as a significant disseminator of deceptive climate rhetoric. In his study, Farrell (2019) quantified the sums of right-leaning private campaign financing through donor organizations like DonorTrust and Donors Capital Fund, which are otherwise virtually untraceable. Farrell (2019) revealed that the presence of people from misinformation networks in philanthropic events and publications rose 443 percent between 1997 and 2007. By employing name recognition technologies, Farrell (2019) conclusively attributed the spread of climate misinformation in philanthropic settings to fossil fuel proponents and/or fossil fuel-funded entities. These include the Cato Institute, the Heartland Institute, and Richard Lindzen, an atmospheric physicist and self-proclaimed denier of climate change. This suggests that the fossil fuel industry plays a ventriloquistic role in the dissemination of climate misinformation.

A myriad of research identified social media as a prominent disseminator of deceptive climate rhetoric (Farrell, 2019; Farrell et al., 2019; Jones, 2014; Lewandowsky, 2021) In addition, Treen et al. (2020) identified algorithmic bias[2] and online identities like robots[3], spammers[4], and astroturfers[5] as prominent spreaders of online climate misinformation. *The New Climate War* explains that bots are, in fact, a particularly

[2] Algorithmic bias is often the work of disseminators of online climate misinformation and refers to the imbalance of ideological positions surrounding a particular issue present in a user's social media feed (Treen et al., 2020).

[3] Robots, or bots for short, are automated accounts on social media platforms that manipulate user conversations and algorithm feeds to increase user engagement with online content (Treen et al., 2020).

[4] Like bots, spammers introduce fictitious user accounts into social networks to control social media users' online experiences. Spammers are different from bots because they are human identities (Treen et al., 2020).

[5] Astroturfers acquire their name from their purpose to coordinate artificial grassroots ("astroturf") campaigns among social media users by disseminating malicious links and manipulating search engines (Treen et al., 2020).

prevalent medium for the dissemination of climate misinformation. Author Michael Mann found that "a quarter of all tweets about climate on an average day are produced by bots" (2021, pp. 68). Treen et al. (2020) found that partnerships between social media platforms and academic researchers may be a promising strategy to reduce the impact of automated messages on the dissemination of climate misinformation. However, additional research is needed to identify how to best address online bots.

The literature reveals that there are systemic mechanisms that perpetuate the spread of climate misinformation, too: homophily[6], polarization, and echo chambers[7]. According to Treen et al. (2020, pp. 1), these mechanisms "provide fertile ground for misinformation to spread." These mechanisms are deeply integrated into the social media posts, circulation of media articles, and algorithmic processes responsible for disseminating climate misinformation.

2.3 Implications

The most direct consequence of climate misinformation is its encouragement of adverse emotional public responses to climate communication from the strategic use of deceptive rhetoric according to individuals' values, belief systems, and lifestyle characteristics. Lewandowsky et al. (2017) found panic, suspicion, fear, worry, and anger to be particularly prevalent sentiments among those exposed to climate misinformation. Negative sentiments toward climate communication also degrade public trust in all shared information and government services and institutions, decrease support for climate policy, exacerbate political polarization and political inaction, prolong climate action, and threaten the overall intellectual wellbeing of democratic societies.

Climate misinformation introduces individuals to cognitive behaviors characteristic of climate skepticism, which reduces public confidence in the scientific evidence for climate change (Treen et al., 2020). Worse, the literature revealed that public denial of fact reduces public trust in all forms of communicated truth (Benegal and Scruggs, 2018; Farrell et al., 2019; Treen et al., 2020). Specifically, increased public denial of shared information caused by climate misinformation threaten societal issues related to the economy and crime (Benegal and Scruggs, 2018; Treen et al., 2020).

Negative sentiments resulting from climate misinformation in conjunction with reduced public trust in scientific fact cultivate a third implication of climate misinformation: decreased public support for climate policy (Aklin and Urpelainen, 2014; Jacques et al., 2008; Lewandowsky et al., 2017; Treen et al., 2020). Aklin and Urpelainen (2014) quantified the consequences of scientific dissent on public support

[6] Homophily is a sociological concept that explains the tendency for individuals to associate with others of similar characteristics (Treen et al., 2020).

[7] Echo chambers describe a network of misinformative literature about climate change circulating from deliberate sharing efforts of climate denialists (Treen et al., 2020).

for environmental policy by assessing 1,000 United States (US) citizens' approval of environmental regulation under scientific consensus levels of 60, 80, and 98 percent. In this context, scientific consensus refers to the proportion of scientists who deem that there is enough evidence to conclude that the supposed environmental issue is present. The study revealed a statistically significant decline in public support for environmental policy beginning at a level of scientific consensus as high as 80 percent (Aklin and Urpelainen, 2014) (Figure 1). Aklin and Urpelainen (2014) did not pose a specific type of environmental regulation to their participants in the experiment, but their results suggest that doing so would demonstrate reduced public support for regulations that address climate change. This study demonstrates that even minimal exposure to climate misinformation can quickly and significantly degrade public support for environmental regulations like climate policies.

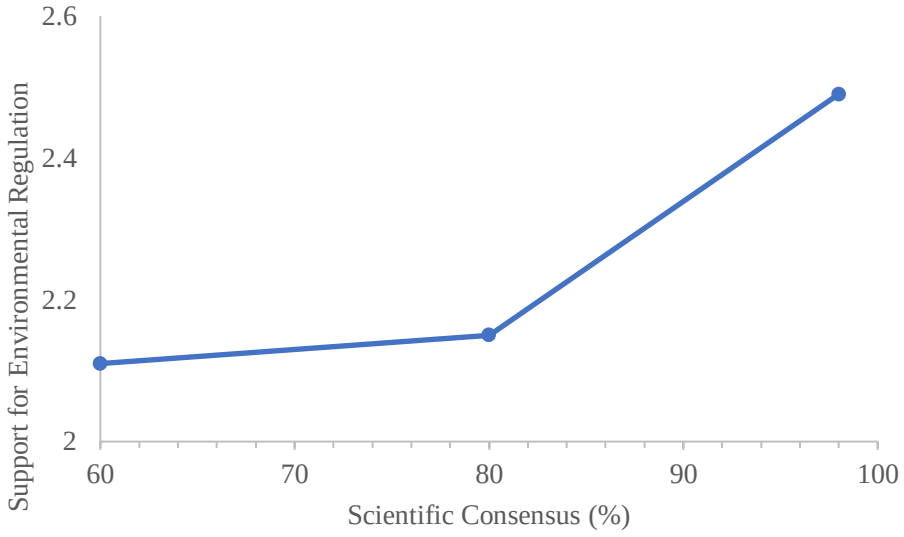

FIGURE 1. Plot of the public support for environmental policy at varying scientific consensuses, redrawn from Aklin and Urpelainen (2014). Support is measured on a scale of 0-4, where higher values indicate stronger support for environmental regulation.

Climate misinformation also exacerbates political polarization by perpetuating inaccurate claims about climate change that are inextricably linked to political values and belief systems (Benegal and Scruggs, 2018; Brulle and Roberts, 2017; Cook et al., 2018; Farrell, 2019; Farrell et al., 2019; Lewandowsky et al., 2017; McCright and Dunlap, 2017; Treen et al., 2020; van der Linden et al., 2017a; Zhou and Shen, 2021). The association of political notions and climate media is far from coincidental; Boussalis and Coan (2018) found that climate misinformation efforts

fixate on denouncing the political leanings of climate action more than skepticizing climate science itself. This is perhaps the most devastating implication of climate misinformation because it discourages individuals from engaging in political discussions altogether (Treen et al., 2020).

The inaction that stems from political polarization consequently prolongs climate action. Jacques et al. (2008) found that climate skepticism stimulated by climate misinformation contributes to a decreased national commitment to addressing environmental protection. This finding reveals the transitive effects of climate misinformation on climate action.

3. Communicators' Responses to Climate Misinformation

Scientists' acknowledgments of the implications of climate misinformation have energized a library of research addressing potential strategies to prevent and counter its spread. Admittedly, climate misinformation is far easier prevented than mitigated (Kaiser et al., 2021). Extant literature identifies attitudinal inoculation as the most effective method for preventing climate misinformation, while other researchers advocate for alternative strategies, like soft power tools and education, to minimize the magnitude of its effects on the public.

3.1 Attitudinal Inoculation

van der Linden et al. (2017a) were the first researchers to apply the theory of attitudinal inoculation in the context of climate misinformation. Attitudinal inoculation involves exposing individuals to weakened versions of inaccurate or misleading information to highlight its false claims and deconstruct potential counterarguments proactively (Treen et al., 2020). van der Linden et al. (2017a, pp. 1-3) sought to evaluate whether it is possible to "inoculate public attitudes" about climate change by presenting its 3,167 participants with statements supporting (*consensus treatments*) and refuting (*countermessages*) the climate consensus in six varying combinations (Table 2).

Treatment number, name	Treatment description	Result of treatment
1. Control group	A neutral word puzzle	N/A
2. Consensus treatment	97% of climate scientists "have concluded that human-caused climate change is happening" (van der Linden et al., 2017b, pp. 7).	Increase in perceived scientific agreement
3. Countermessage	"There is no consensus on human-caused climate change" (van der Linden et al., 2017b, pp. 1).	Decrease in perceived scientific agreement
4. Consensus treatment, countermessage	N/A	Informational value of consensus treatment negated completely
5. Consensus treatment combined with general inoculation, countermessage	"Nearly all climate scientists—97%—have concluded that human-caused climate change is happening. Some politically-motivated groups use misleading tactics to try to convince the public that there is a lot of disagreement among scientists. However, scientific research has found that among climate scientists 'there is virtually no disagreement that humans are causing climate change'" (van der Linden et al., 2017b, pp. 7).	Preserved 1/3 of the positive effect of the initial consensus treatment
6. Consensus treatment combined with detailed inoculation, countermessage	"One such politically motivated group claims to have collected signatures from over 31,000 'scientists'… on a petition urging the US government to reject any limits on greenhouse gas emissions... many of the signatures on the petition are fake… Also, although 31,000 may seem like a large number, it actually represents less than 0.3% of all US science graduates (a tiny fraction). Further, nearly all of the legitimate signers have no expertise in climate science at all… By contrast, 97% of actual climate scientists, agree that human-caused climate change is happening" (van der Linden et al., 2017b, pp. 7).	Preserved 2/3 of the positive effect of the initial consensus treatment

TABLE 2. Experimental treatment conditions used in van der Linden et al. (2017b) study testing the efficacy of attitudinal inoculation theory, explained. Examples taken from Part B: Supplementary Information

van der Linden et al. (2017a) found that communicating only a consensus treatment had a positive influence on the participants' perceived scientific agreement about climate science and communicating only a countermessage had a negative influence on participants' perceived scientific agreement about climate science. However, communicating both a consensus treatment and a countermessage resolved the negative impact of the latter on the participants' perceived scientific agreement about climate science (van der Linden et al., 2017a). This demonstrates that attitudinal inoculation is an effective method for circumventing the impacts of climate misinformation on public perception of climate change. Subsequent research supports the use of attitudinal inoculation to avert climate misinformation (Bonnano et al., 2021; Cook et al., 2018; Lewandowsky, 2021; Maertens et al., 2020; Treen et al., 2020; Zhou and Shen, 2021). Maertens et al. (2020) is a valuable forward search of van der Linden et al. (2017a) that measured both the immediate and chronic efficacy of attitudinal inoculation in avoiding the impacts of climate misinformation. The study found that attitudinal inoculation not only counteracts the negative effects of misinformation entirely, but also prevents depreciation of the impacts of inoculation for more than one week (Maertens et al. 2020). The results reaffirm the potential of attitudinal inoculation to counter climate misinformation, as do those of Bonnano et al. (2021). Bonnano et al. (2021) employed attitudinal inoculation tactics while administering a climate change communication tool kit for the Gulf of Maine about oceanic circulation, sea-level rise, and ocean acidification. The study effectively reduced the public's susceptibility to believing falsities.

3.2 Social media

While a large number of researchers regard social media as a threat to the perpetuation of climate misinformation (Farrell et al., 2019; Farrell, 2019; Gilligan and Gologorsky, 2019; Jones, 2014; Kaiser et al., 2021; Lewandowsky, 2021; Lewandowsky et al., 2017), there also exists a significant pool of researchers who consider social media a tool for countering climate misinformation (Cook et al., 2018; Maertens et al., 2020; Zhou and Shen, 2021). Other researchers acknowledge social media as both a detriment to and potential advocate for climate action (Mavrodieva et al., 2019; McCright and Dunlap, 2017; Treen et al., 2020). Social media is implicated for its haste and manipulative nature that often results in a "lack of rigorous fact-checking and/or twisting of the conclusions" (Gilligan and Gologorsky, 2019, pp. 1). However, Maavrodieva et al. (2019) found that its instantaneous and personalized attributes render it a viable *soft power tool*.

A soft power tool is an instrument with "the ability to influence the behavior of others" to achieve a desirable outcome (Mavrodieva et al., 2019, pp. 4). Mavrodieva et al. (2019) assessed the efficacy of utilizing

social media as a soft power tool to increase public awareness about the climate crisis and inspire positive change in climate-related political processes by analyzing connections between climate-change related events and trends in Internet searches about the events. The study demonstrated promise for using social media to counteract climate misinformation with its finding that social media is an influencer of public opinion, and possibly, political public opinion (Mavrodieva et al., 2019). The review considers social media especially relevant for use among politicians and political organizations since soft power is an effective tactic in politics, and recommends further research to investigate the uses cases of social media for counteracting climate misinformation in political settings.

The study also advocates for the use of social media as a tool of technocognition, which informs the design of digital information by coupling psychological factors with technological innovation (Lewandowsky et al., 2017). This review recognizes Kaiser et al. (2021) as an intriguing example of the use of technocognition to counteract climate misinformation via online security warnings. Online security warnings interact with users to help them avoid "harmful and inauthentic content" (Kaiser et al., 2021, pp. 1). Kaiser et al. (2021) explored the efficacy of security messages with differing considerations for user interaction, partisanship, level of concern for misinformation, and graphics in preventing internet goers from reading material laden with climate misinformation (Table 3). The study revealed that security warnings that require user interaction are more successful than those that do not. The study also found that liberals were more dissuaded from pursuing sources containing misinformation when they encountered signals whose focus was to inform users about the source they selected, whereas conservatives were more dissuaded from pursuing misinformative sources when they encountered signals with an emphasis on relaying harm (Kaiser et al., 2021).

	Most successful warning designs				Least successful warning design
Design ID	i2	i3	i4	h4	h1
Design focus	Informativeness (black on white background)	Informativeness (black on white background)	Informativeness (black on white background)	Harm (white on red background)	Harm (white on red background)
Icon	Policeman	Policeman	Exclamation	Policeman	Skull
Title	Fake News Warning	False or Misleading Content Warning	Fake News Warning	Security Alert	WARNING
Primary message	This website contains misleading or false information.	This website contains misleading or false information.	This website presents itself as news, but it contains information that experts have identified to be false or misleading.	This website contains misleading or false information.	This website is dangerous.
Details	This website spreads disinformation: lies, half-truths, and non-rational arguments intended to manipulate public opinion. It can be difficult to tell the difference between real news and disinformation, but it poses a serious threat to national security, election integrity, and democracy.	Consider finding alternative sources of information.	Consider finding alternative sources of information.	None	None
Group for whom design was successful	Liberals	Liberals	Liberals, conservatives	Conservatives	N/A

TABLE 3. Five of the eight online security messages tested by Kaiser et al. (2021: Table 2) to prevent internet users from continuing to websites containing climate misinformation. Only the messages deemed most and least successful by Kaiser et al. at preventing user engagement with false information are included.

Although technocognition is recognized as a potential approach to combating climate misinformation by other researchers (Cook et al., 2018; Treen et al., 2020), McCright and Dunlap (2017) identified three oversights in supporters' analyses. One oversight is that economic and political interests have a relentless and existential dependency on misinformation for their success, which will likely complicate the eradication of climate misinformation. The researchers cite the complex interconnection between the current distribution of news online and political polarization via echo chambers as another oversight. They reason, "Whether or not conservatives are 'innately' more prone to accept and

promote misinformation than are liberals, the US media landscape nevertheless has far more avenues for the former than for the latter to send and receive misinformation" (McCright and Dunlap, 2017, pp. 393). According to McCright and Dunlap (2017), the intentional promotion of climate misinformation among conservative echo chambers complicates the success of technocognition. Thirdly, the researchers argued that there is false equivalence assumed about the distribution of online news misinformation, and that efforts from the Left to spread climate misinformation are significantly weaker than those from the Right (McCright and Dunlap, 2017). Further research is necessary to explore the efficacy of technocognition as an approach to mitigating climate misinformation.

3.3 Education

Possibly the most widely accepted strategy for preventing and reversing climate misinformation is additional education. The literature encourages education as a strategy to reduce climate misinformation because it reasons that additional education will lessen the number of individuals who mistake climate misinformation for scientific fact (Hobson and Niemeyer, 2012). Further, proponents of education recognize that there is not a "silver bullet" to address climate misinformation, but rather a multi-tiered approach to deconstruct its infiltration into the public realm (Ranney and Velautham, 2021, pp. 139). In the youth education system, Ranney and Velautham (2021) identified nine ways to increase public acceptance of anthropogenic climate change that involve in-nature activities, the scientific method, community-based research, graphs, videos, and maps.

The realities of employing education to combat climate misinformation are, however, quite complex. Although this review identifies education as having an inverse relationship with susceptibility to climate misinformation, it is also true that concern for global warming decreases with college education (Zia and Todd, 2010). This is perhaps because educated students are well-versed in the technologies available to mitigate climate change, so they are less worried about the feasibility of addressing climate change effectively. Additionally, education was not found to impact concern for climate change for college students with conservative ideologies (Zia and Todd, 2010). In other words, political ideology trumps the influence of college education. This raises the question: which educational models are effective for influencing sentiments about climate change?

Zummo et al. (2021) sought to answer this question by selecting more than three hundred high-school-age students who were culturally representative of US citizens to explore the influences of worldview on adolescents' receptivity to climate change education. Zummo et al. (2021, pp. 97) defines "worldview" as a "measurable construct that reflects cultural and social structures valued by a person." Worldviews are associated with political orientation and have been shown to predict an

individual's support for climate policy, acknowledgement of anthropogenic climate change, and skepticism about climate change.

Researchers used two educational models on which to test the influence of worldview: mechanistic understanding and quantitative reasoning. Mechanistic understanding posits that individuals are receptive to the notion of anthropogenic climate change once they garner an understanding of the cause-and-effect relationships within a system (Zummo et al., 2021). In the context of climate change, mechanistic knowledge requires an understanding of the greenhouse gas-emitting processes by which humans alter the climate. Quantitative reasoning is the ability to interpret information mathematically in the form of tables, formulas, figures, and graphs with understandings of their use cases and limitations. Zummo et al. (2021) employs quantitative reasoning to explore the degree to which participants analyze information presented to them about climate change through the filters of their worldviews that support pre-existing beliefs and values.

Zummo et al. (2021) confirmed the suspicion suggested by the discrepancies in the findings from Hobson and Niemeyer (2012), Ranney and Velautham (2021), and Zia and Todd (2010): not all forms of education are effective strategies for counteracting climate misinformation. Mechanistic knowledge about climate change increased an individual's receptivity to climate change. This model was found to be particularly effective when learners were instructed to apply their understanding of the relationships between humans and climate change because it reduced inclinations to use ideologically motivated reasonings to explain climate change (Zummo et al., 2021). Quantitative reasoning was a less effective educational model for improving receptivity to climate change because those who relied more on quantitative reasoning to comprehend climate change were increasingly clouded by worldview. Across both educational models, increasingly conservative worldviews correlated with decreased receptivity to climate change. This suggests that conservative worldviews are also associated with decreased support for climate policy, reduced likelihood of acknowledging anthropogenic climate change, and increased skepticism about climate change.

Additional research is necessary to identify specific educational models that are effective for counteracting climate misinformation as well as to explore the influence of worldview on susceptibility to climate misinformation.

3.4 Additional strategies

Extant literature identifies a multitude of additional strategies for responding to and preventing climate misinformation. These include engaging in messaging that is optimistic, in-group, descriptive, framed, and corrective as well as messaging that emphasizes human relations to nature, cultural connections to climate change, and the scientific consensus on climate change (Chapman et al., 2017; Hornsey and

Fielding, 2020; Jones and Song, 2014; Lewandowsky, 2021; Treen et al., 2020; Wang et al., 2018; Wiest et al., 2015). The literature also suggests deploying early detection strategies and selection mechanisms (Treen et al., 2020).

Despite numerous attempts to elicit environmental support using fear (Wang et al., 2018), Hornsey and Fielding (2020) and Wiest et al. (2015) found that optimistic communication that highlights effective mitigative strategies for reducing the impacts of climate change garners more positive public responses. This is perhaps because the public is not as paralyzed with anxiety about the climate crisis as is often perceived (Hornsey and Fielding, 2020). In fact, negative messaging about climate change can invoke an opposite response that encourages doomsday perspectives about climate action and demotivates individuals from acting.

Hornsey and Fielding (2020) also advocated for in-group climate messaging in comparison to out-group climate messaging after learning that people are significantly more receptive to challenging ideas when they are delivered by an individual of a similar demographic. Further, the use of descriptive ('what is') norms is more effective than injunctive ('what ought to be') norms. Individuals are more motivated to engage in climate discussions and are less likely to fall victim to climate misinformation when they approve of the information presented.

Framing is considered a powerful method when correcting climate misinformation because it customizes values of environmental conservation to those who are less likely to support climate action, such as political conservatives (Benegal and Scruggs, 2018; Hornsey and Fielding, 2020; Treen et al., 2020; Wiest et al., 2015). Benegal and Scruggs (2018) studied the influence of the source of climate communication in correcting climate misinformation and found that Republican communicators of climate news are more effective than both Democrats and climatologists. This is because most climate skeptics and Republicans are conservatives, so climate skeptics are persuaded when Republicans speak against their expected partisan positions (Benegal and Scruggs, 2018). As the findings from Hornsey and Fielding (2020) demonstrate, in-group messaging is likely another contributing factor to the success of Republican communicators in correcting climate misinformation.

Wang et al. (2018) and Lewandowsky (2021) encouraged preventing and reducing climate misinformation by highlighting the emotional connections between humans and the climate crisis. Research demonstrates that implications of the climate crisis on humans' identity, connection to nature, action, future generations, and culture all influence negative sentiments toward climate change. People are more likely to support climate action when they feel that the climate crisis threatens personal values (Jones and Song, 2014; Wang et al., 2018). Lewandowsky (2021) found that emphasizing the scientific consensus of climate change correlates with more successful climate messaging because questioning

the scientific consensus of climate change is a primary tactic of deceptive climate rhetoric.

Treen et al. (2020) advocated for early detection strategies to disable misinformation disseminators like bots, spammers, and astroturfers before they can spread climate misinformation. Establishing partnerships between social media platforms and academic researchers to assist in disabling nonhuman disseminators is essential to the success of this effort. Sarathchandra and Haltinner (2021) strengthened the viability of early detection strategies as a method for counteracting climate misinformation via the development of an objective measurement for climate skepticism. The *(dis)trust in climate science* survey instrument has potential for future application to reduce alienation in the climate science community by comparing skeptic views to those of the general public (Sarathchandra and Haltinner, 2021).

Research that highlights the use of selection mechanisms to reduce the prevalence of online climate misinformation suggests employing algorithms to crowdsource the quality of climate news content. It reasons that social media platforms possess a responsibility to counter climate misinformation (Treen et al., 2020).

4. The Future of Climate Communication

Informing the public about climate science alone is insufficient in the presence of climate misinformation that is reducing public concern for climate change and advocacy for climate policy. Future climate communication efforts must also triumph deceptive climate rhetoric. In their review of more than one hundred research articles addressing the theory and language of effective climate communication, Nerlich et al. (2010) suggested that all climate communication efforts begin with an evaluation of an audience's existing views and knowledge about climate change to craft optimally compelling and valuable messages specific to the public demographic engaged.

Utilizing appropriate levels of cognitive complexity when relaying climate information is another strategy for overcoming climate misinformation (Chen and Unsworth, 2019). Catering climate communication according to cognitive complexity maximizes the efficacy of countering misinformation because extant research demonstrates that susceptibility to climate misinformation decreases with more education (Chen and Unsworth, 2019; Hornsey and Fielding, 2020; Wang and Kim, 2018; Zia and Todd, 2010). Similarly, Ranney and Velautham (2021) recommended that communicators explain scientific evidence so that readers may detect climate misinformation more easily.

The research also advocates for the use of in-group messaging to communicate climate change effectively (Hornsey and Fielding, 2020). Gainous et al. (2021) recommended citing the US Environmental Protection Agency (EPA) in climate communications because their

research revealed that both liberals and conservatives regard the EPA as a trustworthy source for climate science. Increased emphasis on the anthropogenic nature of climate change is also advised because research reveals that attention to human influences on the existing climate crisis is insufficient (Ranney and Velautham, 2021). As well, climate communication efforts must engage with climate change skeptics because research supports that these interactions inspire notable reductions in susceptibility to climate misinformation (Hobson and Niemeyer, 2012).

Reduced public trust in climate dialogue imposed by deceptive climate rhetoric suggests that climate communicators should follow established best practices when relaying climate science. Established best practices include acknowledging the uncertainty of scientific studies, refraining from the use of emotional appeals, and considering the credibility of a message with regard to its source (Mah et al., 2020). Climate communicators might also consider juxtaposing striking imagery with scientific information to restore public trust in climate science (Guenther, 2020).

To overcome climate misinformation, scientists and communicators must also remain aware that its tactics are everchanging. The increasing prevalence of climate change throughout the facets of daily life compel disseminators of climate misinformation to adapt their strategies to remain effective. As Michael Mann explained in *The New Climate War*, climate misinformation often no longer involves outright denial of climate change (2021). Rather, more nuanced tactics are necessary, including deflection, division, delay, despair-mongering, and doomism (Figure 2) (Mann, 2021). Effectively combating climate misinformation involves triumphing all five of these tactics and whichever others develop in response to modern climate science.

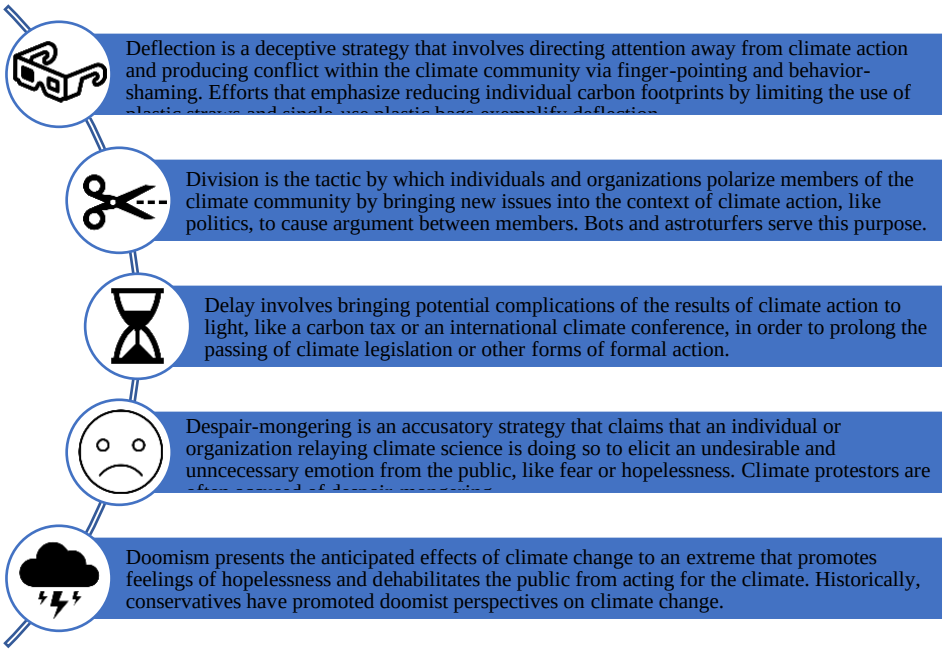

FIGURE 2. Graphic delineating the modern forms of climate misinformation that have resulted from disseminators of climate misinformation adapting to the increased prevalence of climate change (Mann, 2021).

5. Discussion

It is difficult to dispel climate misinformation in the minds of the public after consumption, and climate misinformation has detrimental consequences on social and political decisions. Thus, a thorough evaluation of the extant literature is essential to improve the efficacy of future research that attempts to further explain and counteract climate misinformation.

For a field in which diction is critical for formulating public perception, the prevalence of researchers' use of the phrase "believe in climate change" to describe surveyed participants' attitudes on anthropogenic climate change was disappointing. Nearly half of the articles reviewed contain the phrase. The perpetuation of this dialogue, especially by climate communicators themselves, contributes to the skepticism about the realities of climate change among 20 percent of the American public (Sarathchandra and Haltinner, 2021). Future research articles must refrain from using the word "believe" to describe public sentiment about climate change because, as McCright and Dunlap (2017, pp. 390) explained, "truths exist external to [the] mind." Granting individuals a choice to subscribe to anthropogenic climate change creates a space for debate about the scientific consensus that should not exist. When relaying public attitudes about climate change, researchers should use "accept" or "acknowledge" in place of "believe."

Another prevalent flaw in the reviewed literature is the experimental design of the research experiments that used human participants (Table 4). Several researchers had the potential of contributing more to the field of climate misinformation with a larger sample size. Hobson and Niemeyer (2012), for example, incorporated only 103 individuals in their experiment that explored the impact of educational intervention on climate change skeptics. Worse, Sarathchandra and Haltinner (2021) included 33 participants to develop their *(dis)trust in climate science* survey instrument. Participant pools of sizes like these are insufficiently small to represent larger populations with reliable accuracy.

Study	Research focus	Sample size	Survey instrument/ methodology
Aklin and Urpelainen (2014)	Impact of scientific dissent on public support for environmental policy	1,000	Opt-in, YouGov/Polimetrix survey
Benegal and Scruggs (2018)	Impact of partisanship on correcting climate misinformation	1,306	MTurk
Chen and Unsworth (2019)	Relationship between likelihood of acknowledging climate change and cognitive complexity	1,347	Qualtrics
Connor et al. (2016)	Comparative prevalence of framing methods used to communicate climate change by social media users	219	MTurk
Gainous et al. (2021)	Impact of source cues or frames on perceived truth of climate science	1,002	Qualtrics
Hobson and Niemeyer (2012)	The impact of education intervention on climate change skeptics	103	Commonwealth Scientific and Industrial Research Organization's (CSIRO) OzClim model; Q Method
Jones (2014)	Influence of narratives about climate change on climate change policy preferences	1,711	Online surveys administered by Survey Sampling International (SSI)
Jones and Song (2014)	Impact of story frames on the reception of climate information	2,005	Online surveys administered by Survey Sampling International (SSI)
Kaiser et al. (2021)	Efficacy of eight warning designs on dissuading exposure to online disinformation	278	MTurk
Krosnick et al. (2006)	Determinants of Americans' concern for global warming	1,413	Computer-assisted telephone interviews; Attitude, Certainty, and Existence (ACE) Model
Linden et al. (2017a)	Efficacy of attitudinal inoculation on countering climate misinformation	3,167	MTurk
Maertens et al. (2020)	Long-term efficacy of attitudinal inoculation on counteracting climate misinformation	415	Prolific, Measurement of Perceived Scientific Consensus (PSC)
Sarathchandra and Haltinner (2021)	*(dis)trust in climate science* survey instrument to measure climate skepticism	33	Qualtrics
Wang and Kim (2018)	Impact of values and perception on climate change	Varies according to sample data used in analysis	Varies according to sample data used in analysis
Wang et al. (2018)	Impact of emotions on predicting support for climate policy	343	Survey administered to college students with incentive for course credit
Wiest et al. (2015)	Efficacy of varying framing methods of climate change on public opinion	198	Qualtrics
Zia and Todd (2010)	Impact of ideology on public attitude toward global warming and four other socioeconomic issues	655	Participant interviews
Zhou and Shen (2021)	Chronic impacts of climate misinformation on discrediting scientific evidence	408	Qualtrics
Zummo et al. (2021)	Influence of three education types on receptivity to climate change	357	Culturally representative sample of students (grades 9-11) from five US high schools

TABLE 4. Synthesis of the experimental designs of the reviewed articles that performed research experiments using human participants.

Much of the reviewed literature also relied on online platforms to conduct experiments, like Amazon Mechanical Turk (MTurk) (Benegal and Scruggs, 2018; Connor et al., 2016; Kaiser et al., 2021; Linden et al., 2017a), Qualtrics (Chen and Unsworth, 2019; Gainous et al., 2021; Sarathchandra and Haltinner, 2021; Wiest et al., 2015; Zhou and Shen, 2021), and other Internet means (Aklin and Urpelainen, 2014; Hobson and Niemeyer, 2012; Jones, 2014; Jones and Song, 2014). The use of online platforms for research introduces credibility concerns because of the voluntary and compensated participation common among them. The inconclusive results regarding the influence of education level on susceptibility to climate misinformation from Sarathchandra and Haltinner (2021)'s study were a result of biased sampling. The study, administered via Qualtrics, relied on self-proclaimed climate skeptics of the US Pacific Northwest (Sarathchandra and Haltinner, 2021).

An unexpected finding from this review is that race is not a significant influence on an individual's susceptibility to climate misinformation (Hornsey and Fielding, 2020). Race is heavily intertwined with considerations for income and experience with extreme weather due to the notions of environmental injustice, which positions minoritized communities disproportionately closer to experiencing the impacts of climate change than their White counterparts (Johansen, 2020). Therefore, it is reasonable to presume that individuals of different races present varying susceptibilities to climate misinformation. The influence of race on climate perception was an uncommon variable in the reviewed literature, so additional research is suggested to investigate this discrepancy.

A critical consideration when interpreting the findings of the literature, as the example of environmental injustice illustrates, is that the reviewed values, belief systems, and lifestyle characteristics in Section 2.1 often have overlapping influences on one another. For this reason, this review also encourages research that considers the intersectionality of the factors that influence an individual's susceptibility to believing climate misinformation.

Another useful application of the findings from Section 2.1 is to identify US regions that are more susceptible to climate misinformation than others. Projecting the averages of each of the factors examined in Section 2.1 (e.g., average values for average age, education level, income, extreme weather probability, political affiliation, etc.) onto a map may be one such way to identify susceptible locations. Having this knowledge could direct the deployment of mitigative efforts for climate misinformation by targeting US regions that coincide with factors with high likelihoods of falling victim to climate misinformation.

Evaluating McCright and Dunlap (2017) revealed the need for additional research on the implications of climate misinformation according to the mode by which it is disseminated. Farrell et al. (2019)

suggested deploying social science research and public vigilance efforts to better detect misinformation as well as more public funding to improve the financial transparency of scientific misinformation and, ultimately, prevent its dissemination. As well, analyzing Treen et al. (2020) identified the limited knowledge base about the jarringly heavy hand that automated bots have on the dissemination of climate misinformation on social media platforms. Further research is recommended to identify strategies to combat their contributions to climate misinformation.

6. Conclusion

Although not always intentional, climate misinformation involves the distribution of rhetoric about climate change that is initially deemed truthful but later revealed inaccurate. Fossil fuel proponents and bad state actors have relied on the tactful creation and dissemination of climate misinformation for approximately seventy years by catering to public values, belief systems, and lifestyle characteristics. Research demonstrates that attention to demographic factors influences an individual's vulnerability to deceptive messages. This often inflicts several negative consequences on an individual's support for climate action, including increased political polarization, prolonged climate action, and complete disinterest in politics altogether.

Several researchers have recognized the significance of formulating strategies that counter climate misinformation to restore the credibility of climate policy. Attitudinal inoculation, social media, education, and messaging that is framed, descriptive, and optimistic are the fruits of their labor. Employing these strategies while also pursuing additional research that further explores how to deconstruct deceptive climate rhetoric are essential next steps to exploring climate misinformation. This will prove paramount to a society experiencing the realities of an intensifying climate crisis.

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