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Social Media, Political Polarization, and Climate Change: A Systematic Literature Review

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ABSTRACT

Research on environmental communication reveals that addressing the impact of social media on climate change-related discussions is urgently needed if we are to accelerate the transition toward climate-neutral societies. To this end, this systematic literature review presents the findings of a content analysis of 27 peer-reviewed scientific articles investigating the relationship between social media, political polarization, and climate change—preceding Elon Musk's bid to acquire Twitter on April 14, 2022. The review yields contradictory findings with regard to the degree of polarization in climate change-related conversations on social media: 13 publications find some instances of polarization, 6 report none, and 8 remain inconclusive. Despite these divergent results, the review points to clear relationships between the existence of polarized climate change-related conversations in the studies' findings and their foci, type of data employed, and forms of polarization approached. Specifically, polarized climate change-related discussions on social media clearly overshadow studies that explore communicative interactions, utilize digital trace data, and address affective polarization. In contrast, in publications investigating the effects of exposure to climate change-related information on social media, particularly those relying on self-reported data to examine ideological polarization, the predominant trend is either the absence of polarization or inconclusive results.

Keywords: Social Media, Political Polarization, Climate Change, Systematic Literature Review.

INTRODUCTION

With regard to climate change, political polarization – broadly understood as a "marked political division in the population" (Weber et al., 2021) – has arisen in parallel to people's increasing use of social media, averaging 2 hours and 24 minutes per day according to a global survey conducted in October 2023 (We are social, 2023). Social media is defined here as "any website or web-based service that includes web 2.0 characteristics and contains some aspect of user generated content" (Gruzd, Staves, & Wilk, 2012, p. 2,341). This increased use has induced many scholars to investigate whether, how, and to what extent social media contributes to a polarized environmental discourse (Röchert et al., 2020; Williams et al., 2015). In general, these studies reveal that views on climate change are divided along ideological and partisan lines. Even in countries with lower levels of skepticism about climate change, the proponents and opponents of mitigation policies still tend to be hostile toward one another (Chen et al., 2021).

Polarized discussions about the environment have been shown to have several negative effects, including undermining public confidence in human-caused climate change, increasing political inaction (Bruelle, 2014), and delaying or impeding mitigation efforts (Cook et al., 2018). There is also substantial evidence for "backfire" or

"boomerang" effects in highly polarized media environments in which climate communication meant to boost support for mitigation policies (e.g. increased spending) instead fuels resistance from groups that oppose taking strong countermeasures (W. Chen, Pacheco, Yang, & Menczer, 2021). Addressing the impact social media has on climate change-related discussions is thus fundamental to the realization of climate-neutral societies and prevention of social unrest. This is particularly important in pluralistic political regimes, where highly polarized environments have the "potential to drive antagonism between ideological groups, generate political deadlock and threaten pluralist democracies," as Falkenberg et al. contend (2021, p. 1).

The first step to addressing this schism is a better understanding of the characteristics of climate change-related political polarization on social media. Despite the urgency of the climate situation, research into the causes and effects of polarized public views in this area remains limited. Moreover, there has to date not been, to the best of our knowledge, a comprehensive account of the disparate scientific work that has been done on climate change-related polarization on social media. Our systematic literature review represents such an endeavor. It presents a unique taxonomy of scientific works on the matter, shedding light on their different theoretical lenses and methodological approaches, points of alignment and divergence, benefits and drawbacks. Offering such a comprehensive and critical analysis will hopefully inspire more research in the field.

Specifically, this systematic literature review presents the findings of a content analysis of 27 peer-reviewed scientific articles investigating the relationship between social media, political polarization, and climate change (see Appendix 1). It provides a thorough overview of the trends and dissonances across these studies in terms of their areas of focus, methods, and results. We then move on to a discussion of these commonalities and differences, and offer specific conclusions about the current state of the field.

Similar to Terren and Borge's (2021) literature review on social media and echo chambers, our analysis also reveals a division between research focusing on social media communication and interaction, on the one side, and studies concentrating on the effects of content exposure on social media, on the other. A similar split between studies employing digital trace data and research using self-reported data is also evident. However, unlike Terren and Borge's results, though, most of the studies included in our systematic literature review depart from the assumption that the discourse about climate change on social media is subject to polarization, serving as a premise for assessing the degree of polarization, its linguistic features, and its repercussions for individuals' climate change-related beliefs and attitudes.

All in all, this systematic literature review presents a first classification of the peer-reviewed literature on social media, political polarization, and climate change. It serves to depict the diverse foci, methodological approaches, and results obtained here. In doing so, it aims to foster further research on this key topic.

DATA AND METHODS

This systematic review considers scientific studies that have examined political polarization regarding climate change-related discussions on social media, written in English, and published online in peer-reviewed journals or conference proceedings between January 1, 2005 (roughly corresponding with the advent of modern social media platforms) and December 31, 2021 (prior to Elon Musk's bid to acquire Twitter on April 14, 2022). It follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol in order to: (a) provide state of the art knowledge in the field; (b) identify existing research gaps and challenges; and (c) make recommendations for future research (Page et al., 2021).

Exclusively focusing on articles published in peer-reviewed journals or conference proceedings that address social media, political polarization, and climate change meant disregarding a number of seemingly relevant or otherwise related studies. Several of these focus on polarization in online climate change-related discussions, but not on social media specifically (Adam, Häussler, Schmid-Petri, & Reber, 2019; Collins & Nerlich, 2015; Häussler, 2019). Other discarded work addresses polarization in the context of climate change-related discussions, but focuses instead on traditional media — for example, Bohr's (2020) analysis of partisanship and bias vis-à-vis climate change reporting in print newspapers. Furthermore, there are a number of studies that examine climate change-related discussions between those holding opposing views on social media, but they do not specifically examine polarization (Bounegru, De Pryck, Venturini, & Mauri, 2020; Huntington & Anderson, 2015).

Nevertheless, the decision to restrict the criteria for inclusion to peer-reviewed journals and conference proceedings was taken to ensure the manageability and transparency, and aligns with the methodological norms of such systematic reviews (Page et al., 2021). The selection criteria for this systematic literature review meant overlooking reports, reviews, books, and book chapters of potential relevance (e.g., Bridge, 2021), as well as news articles and studies published in languages other than English. As such, our study by no means encompasses all of

the existing literature on social media, political polarization, and climate change, and rather it should be seen as a representative collection of the academic literature in English examining political polarization in climate change-related discussions on social media.

To identify and retrieve relevant studies focusing on social media, political polarization, and climate change existing as peer-reviewed journals and conference proceedings, we employed a clearly defined keyword search in three of the most popular social science academic research databases (Chadegani, 2013): Web of Science, Scopus, and ScienceDirect. Additionally, such a search was also performed via Google Scholar. We used Boolean searches with the following keywords: "social media" AND "polarization" AND "climate change" (see Appendix 2 for further details). This was a topic search that identified correspondence based on titles, abstracts, and keywords. Due to the inflated number of relevant studies for the search in Google Scholar (in excess of 15,000 results), we selected the first 500 (as sorted by relevance). The searches in Web of Science (31 results), Scopus (276 results), ScienceDirect (286 results), and Google Scholar (first 500 results) together yielded 1,093 studies that were carefully assessed for eligibility (**Figure 1**). First, we checked the 1,093 studies for duplicates (n=89). Subsequently, we reviewed the titles and abstracts of the remaining 1,004, with two researchers carefully reading the titles and abstracts of the manuscripts to determine whether they should be kept or excluded from the analysis. Of the 1,004 articles, 952 studies were excluded as they were not about social media, polarization, and climate change (n=703), were not peer-reviewed articles or included in conference proceedings (n=246), or were not written in English (n=3). Next, both researchers conducted an in-depth, full-text screening of the remaining 52 articles, leaving them with 27 studies eligible for inclusion in our systematic literature review (see Appendix 3 for the discarded 25 articles).

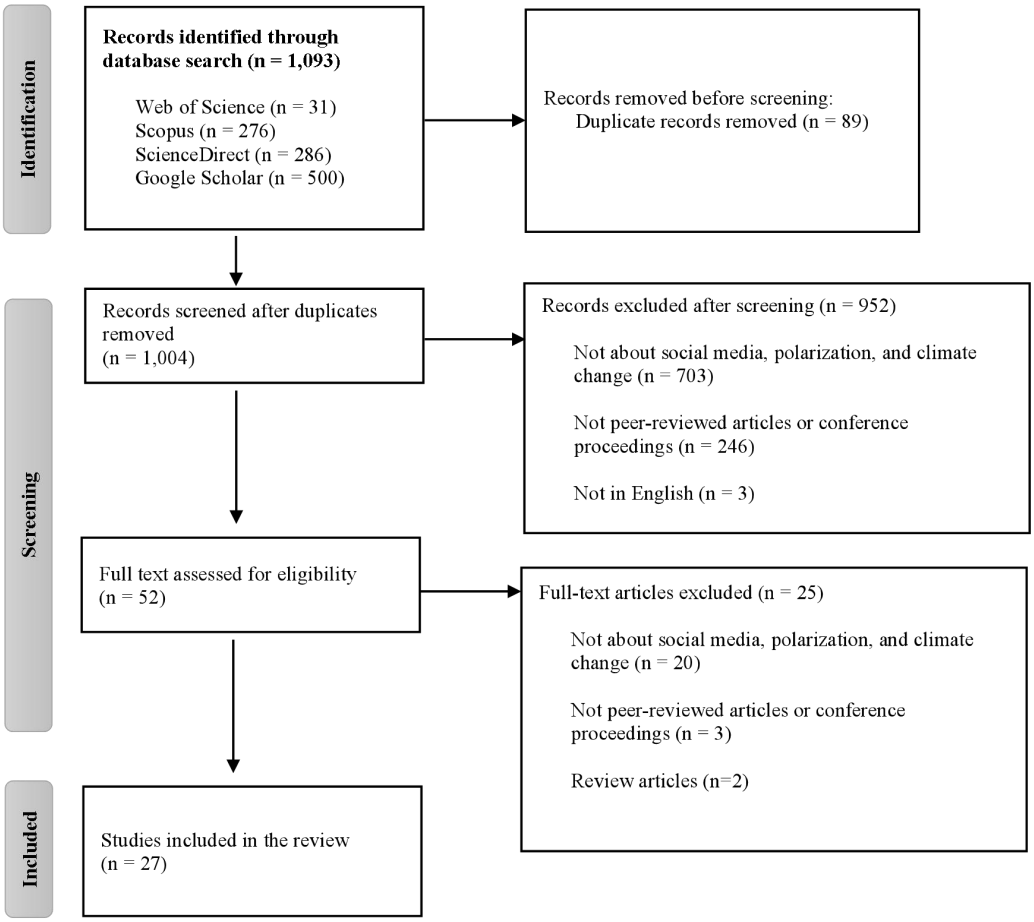

Figure 1. PRISMA Flow Diagram of Eligibility Assessment Process

During the screening process, an analytical framework was developed to identify research aims, foci, and questions, types of data, methods of analysis, as well as findings for each of the articles included in the final sample. Furthermore, a keyword search was conducted with the open-source software R (R Core Team, 2022), using the package 'pdftools' (Ooms, 2022). The results of the systematic literature review are organized according

to three key areas: foci, methods, and findings. We seek to outline recurring trends, strengths, and weaknesses in the examined studies, further to providing also a broad overview of the state of the art in the academic debate on social media, political polarization, and climate change.

RESULTS

While our keyword search targeted articles written between 2005 and 2021, the final sample of studies included in this systematic literature review was published between 2014 and 2021 alone, with a sharp increase identifiable therein from 2020 (**Figure 2**). This seems to suggest that research on social media, political polarization, and climate change is still in its infancy.

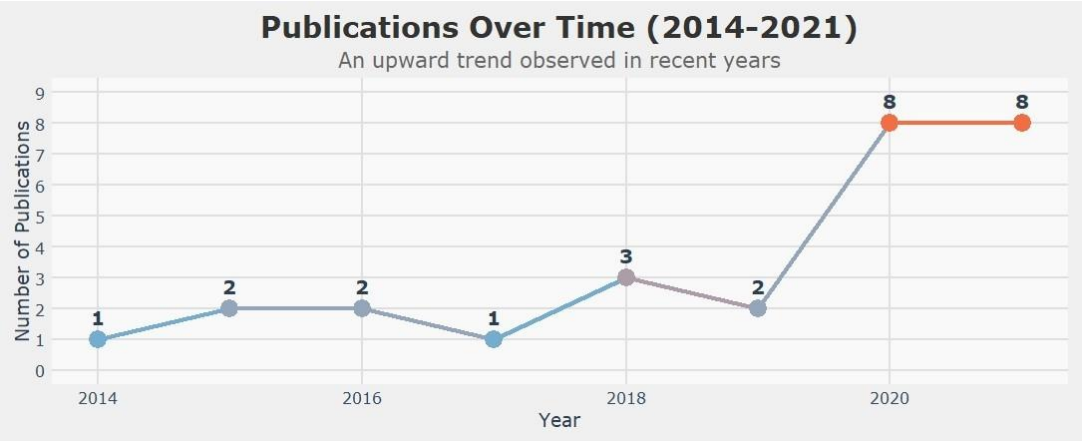

Figure 2. Number of Studies Published on Social Media, Polarization, and Climate Change (2014-2021)

As for the occurrence of analytically relevant keywords, **Figure 3** indicates a "politicization" of discussions on social media, polarization, and climate change. This is not only apparent through the occurrence of the word "politics" (n=1,070), but also through the occurrence of ones such as "partisanship" (n=235) and "ideology" (n=233). Figure 3 also reveals two further key aspects of such discussions, indicated by the numerous occurrences of the words "networks" (n=991) and "communities" (n=480) respectively.

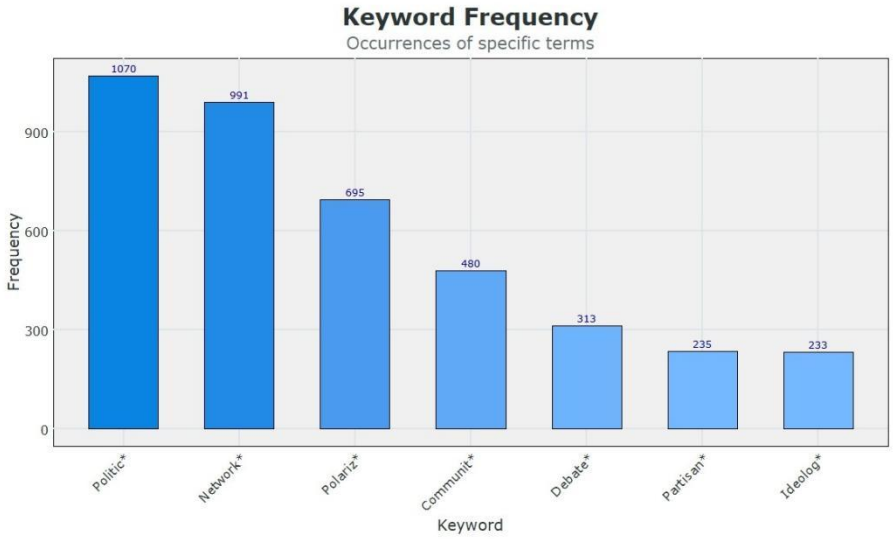

Figure 3. Keyword Frequency across All Articles Included in the Systematic Literature Review (Note: This includes multiple variants of these words: e.g. Politic* accounts for "politics," "political," and "politically.")

Foci

Most studies included in this systematic literature review are based on the assumption that polarization exists in social media discussions about climate change, suggesting that research in this area has now moved beyond seeking to prove the reality of such a schism. With regard to research foci, a broad distinction can be made between studies (a) focusing on communicative interactions within and between climate change-related communities on social media and (b) those examining the effects of exposure to climate change-related information on social media. The first group scrutinizes polarization vis-à-vis climate change-related discussions on social media by looking at the characteristics of these communicative interactions, while the second investigates the impact that exposure to climate change-related information on social media has on users.

Studies Focusing on Communicative Interactions within and between Climate Change-related Communities on Social Media

The vast majority of the studies included in our systematic literature review investigate polarized communicative interactions regarding climate change on social media (Moernaut, Mast, Temmerman, & Broersma, 2020; Chen et al., 2021). Within this group of studies, several engage with the linguistic features of such polarized climate change-related discussions. For example, Anderson and Huntington (2017) turn to the use of sarcasm and incivility in Twitter discussions about climate change during an extreme-weather event; Olausson (2018) investigates the legitimation of livestock production in everyday discourse on Facebook; Meza, Shapiro, and Park (2018) study the topics, sentiments, and argumentative mechanisms informing climate change-related YouTube comments; and, Al-Rawi, O'Keefe, Kane, & Bizimana (2021) examine the role of the term "fake news" in climate change-related discussions on Twitter. Related studies examine the linguistic differences between users or communities on either "side" of the climate change debate. Jang and Hart (2015) address differences in preferred language use when it comes to climate change's communication for those accepting and questioning the phenomenon's existence respectively; Tyagi, Babcock, Carley, and Sicker (2020), and Tyagi, Uyheng, and Carley (2020) quantify hostile communication on Twitter, dividing between those who believe in the anthropogenic causes of climate change (believers) and those who are skeptical of this view (disbelievers); and, Cann, Weaver, and Williams (2021) assess how ideological orientation affects the behavior of sharing content online for left-wing environmentalists versus right-wing climate skeptics.

A second stream of research primarily examines the structural features of climate change-related communities that exist on social media. These studies identify the network structures of related online discussions and assess, through an examination of the frequency of the communicative interactions within and between climate change-related communities on social media, whether these users mostly interact with like-minded individuals or with those who think differently (Röchert et al., 2020; Williams et al., 2015). Other studies approach polarization within climate change-related discussions on social media by focusing on the individual characteristics of the opposing communities' members—comparing, for instance, the social media consumption patterns of people with a high-risk perception regarding climate change versus those with a low-risk view (van Eck, Mulder, & van der Linden, 2021). Studies also examined whether a relationship exists between users' political affiliation and their stance on climate change (Helmuth, Gouhier, Scyphers, & Mocarski, 2016).

Lastly, several studies explore both the linguistic features of the polarized communication occurring between climate change-related communities on social media and the defining characteristics of these collectives. Pearce, Holmberg, Hellsten, and Nerlich (2014) note the topics addressed in climate change-related discussions on social media with regard to the 2013 IPCC Working Group 1 report; Arlt, Rauchfleisch, and Schäfer (2019) study the linguistic and topological differences between climate change-related communities on social media; and, Marlow, Miller, and Roberts (2021) analyze the presence of bots in climate change-related conversations on Twitter and the topics that these entities address in their tweets.

Studies on the Effects of Exposure to Climate Change-related Information on Social Media

Although most of the work included in this review investigates climate change-related communicative interactions within and between communities on social media, close to one-third of them specifically analyze the effects of being exposed to climate change-related information on social media. Most of these studies address the effects of exposure on individual beliefs. For example, Samantray and Pin (2019) conducted Twitter conversations about climate change (2007–2017) to assess the impact of homophily on the polarization of individual viewpoints; and Diehl, Huber, Gil de Zúñiga, and J. Liu (2021) evaluated the consequences of news consumption via social media for people's climate change-related outlooks. A second group of studies scrutinize the effects of exposure to climate change-related information on social media on a user's subsequent engagement with climate-related topics on these platforms. Chapman, Corner, Webster, and Markowitz (2016) study users' perceptions and reactions to photographic climate change-related material shared on social media; Jennings, Allen, and Le Vu Phuong (2021) investigate how Democrats and Republicans in the United States respond to environmental information disseminated via social media. Lastly, there is a group of studies that explore the effects on

deliberation that come from exposure to climate change-related information on social media. Shapiro and Park (2018) examine YouTube's potential to facilitate political deliberation about climate change; more recently, Serrano-Contreras, García-Marín, and Luengo (2020) have turned to whether exposure to a polarized climate change discourse on YouTube increases a user's subsequent deliberation on the topic.

Overall, this systematic literature review suggests that the analysis of the effects of the exposure to polarized climate change-related discussions on social media has been met with significantly less attention than has the study of the nature of the communicative interactions within and between climate change-related communities on social media.

Methods

The works included in this systematic literature review employ a wide range of methodological approaches. A broad distinction can nonetheless be made between those that examine polarized climate change-related discussions on social media via the use of digital trace data (n=21) and those that investigate such discussions using self-reported data (n=6). Of note, none of the studies included in the review combine digital trace data and self-reported data.

Studies Using Digital Trace Data

"Digital trace data" refers to records that are generated as a result of human interaction with any kind of digital device (Hakimi, Eynon, & Murphy, 2021). In the papers reviewed in this study, this primarily refers to data generated as a result of human interaction on social media. The vast majority of the studies using digital trace data garnered records from Twitter (n=15), followed by YouTube (n=4). The prevalence of Twitter can be explained by the suitability of the platform's affordances to facilitating dialogical communications as well as the (previously) relatively easy access to its data through its open-source application programming interface (API)[1]. None of these studies using digital trace data combine assessments of multiple platforms, limiting the generalizability of their findings.

Across the sample, social network analysis (SNA) is the most prevalent method used by the studies relying on digital trace data. SNA generally seeks to conceptualize social structures by focusing on the ties (represented by messages/comments, e.g. tweets, Reddit comments, etc.) between its nodes (e.g. individual users, organizations, states, etc.) on social media platforms (Otte & Rousseau, 2002). In the literature, SNA has been employed both exclusively and in combination with other methods. Williams et al.'s (2015) assessment of the degree of homophily between climate change-related communities on Twitter and Shapiro and Park's (2018) examination of the structure of YouTube discussions about popular climate change-related videos are two examples of its exclusive use. As for its combined use, Brüggemann et al. (2020) employ SNA and content analysis to identify patterns in hoax online discourses on climate change; Uyheng et al. (2021) characterize the polarized ecosystem of online climate change-related discourse via a mix of SNA and quantitative content analysis; and, Röchert et al. (2020) examine opinion-based homogeneity on YouTube within and between different communities regarding climate change via their blending of SNA and sentiment analysis.

On the other hand, a much wider variety of methodological approaches can be observed among those studies that exclusively employ content analyses of polarized climate change-related discussions on social media. Several studies make use of quantitative and qualitative content analysis, for example, exploring sarcasm and incivility in Twitter discussions about climate change during an extreme-weather event (Anderson & Huntington, 2017). Other investigations employ topic modeling to examine the nature of the content produced by bots (Marlow et al., 2021). A further study combines computational and manual text-based methods (i.e. sentiment analysis and discourse analysis) to examine users' emotions and impressions vis-à-vis climate change-related comments on YouTube (Röchert et al., 2020).

Studies Using Self-reported Data

Within papers relying on self-reported data that were included in this study, data is primarily gathered from participants being asked about their social media use, their interpretation of climate change-related messages, and their beliefs about the phenomenon (Lavrakas, 2008). When focusing on individuals' behaviors, attitudes, and beliefs, self-reported data is highly suited for studies of the effects of polarized climate change-related discussions on social media. This is visible throughout our sample, since all the studies using self-reported data—with one exception (van Eck et al., 2021)—focus on the repercussions of exposure to climate change-related content on social media.

Most of the studies using self-reported data make use of surveys to collect such information. Several of these

[1] On February 1, 2023, Twitter announced that it would no longer support free access to the platform's API. This decision is expected to have serious consequences for researchers' future collection and analysis of Twitter-related data.

measure how climate change-related news is received by users—by, for instance, combining responses to a survey and a social-learning model to test the effects of exposure to climate change-related information on participants' beliefs (Sikder, Smith, Vivo, & Livan, 2020), or alternatively by conducting a multilevel regression analysis to test social media's impacts on attitudes toward the phenomenon (Diehl et al., 2021). Another study performs a cross-sectional examination of the effects of differing climate-related risk perceptions on blog consumption (van Eck et al., 2021); whereas Yuan and Lu (2020) break down the effects of aggressive communication styles on climate-related behaviors through the use of structural equation modeling.

Exceptionally, we found two studies mixing quantitative survey research with qualitative methods. Chapman et al. (2016) blend the use of a survey with discussion groups to investigate public perceptions of climate change-related images in three countries. Jennings et al. (2021), meanwhile, combine a survey with cognitive map drawing to measure partisan responses to climate change-related video content on social media.

In summary, as shown in **Table 1**, most of the publications included in this systematic literature review employ digital trace data (19 out of 27), while a minority use self-reported data (8 out of 27). Furthermore, those that use digital trace data predominantly focus on the structural characteristics of users' communicative interactions (18 out of 19 studies). Among these studies, SNA seems to be the preferred method to identify network structures, while scholars are inclined to use a wider variety of approaches when examining the content of polarized climate change-related discussions on social media. On the other hand, the studies using self-reported data mostly focus on the effects of exposure to polarized climate change-related discussions on social media (5 out of 8 studies). Among these, surveys clearly lead when it comes to the collection of data.

Table 1. Classification of the Publications Included in this Systematic Literature Review Based on Their Foci, Types of Data, Types of Polarization and Existence of Polarization

Article	Foci		Type of Data		Type of Polarization			Existence of Polarization		
	Communicative Interactions	Effects of the exposure to climate change-related information	Digital trace data	Self-reported data	Ideological Polarization	Affective Polarization	Elite Polarization	Present	Absent	Inconclusive
Marlow et al., 2021	X		X		X					X
Al-rawi et al., 2021	X		X			X		X		
Cann et al., 2021	X		X		X			X		
Chen et al., 2021	X		X		X				X	
Van Eck et al., 2021	X			X	X			X		
Jennings et al., 2021		X		X	X			X		
Uyheng Tyagi, and Carley, 2021	X		X			X		X		
Diehl et al, 2021		X		X	X				X	
Moernaut et al., 2020	X		X			X		X		
Serrano-contreras et al., 2020		X	X			X			X	
Tyagi, Babcock et al., 2020	X		X			X		X		
Sikder et al., 2020		X		X	X					X
Bruggemann et al., 2020	X		X			X		X		
Rochert et al., 2020	X		X		X				X	
Tyagi, Uyheng et al., 2020	X		X			X		X		
Yuan & Lu., 2020		X		X		X				X
Samantray and Pin, 2019		X	X			X			X	
Arlt et al., 2019	X		X		X				X	

Article	Foci		Type of Data		Type of Polarization			Existence of Polarization		
	Communicative Interactions	Effects of the exposure to climate change-related information	Digital trace data	Self-reported data	Ideological Polarization	Affective Polarization	Elite Polarization	Present	Absent	Inconclusive
Olausson, 2018	X		X		X			X		
Shapiro and Park, 2018		X	X				X			X
Meza et al., 2018	X		X				X			X
Anderson et al., 2017	X		X		X					X
Chapman et al., 2016		X		X	X					X
Helmuth et al., 2016	X		X		X			X		
Jang and Hart, 2015	X		X			X				X
Williams et al., 2015	X		X			X		X		
Pearce et al., 2014	X		X			X		X		

Findings

The findings of the studies assessed in this systematic literature review can be classified into three different categories, discerning between research: a. On the relationship between the studies' foci and the existence of polarized climate change-related communications on social media; b. on the relationship between the studies' types of data and the existence of polarized climate change-related communication on social media; and c. on the relationship between the studies' different forms of political polarization and the existence of polarized climate change-related communications on social media.

On the Relationship between the Studies' Foci and the Existence of Polarized Climate Change-related Communications

With regard to the relationship between the studies' foci and the existence of polarized climate change-related communications, two findings can be identified: a) based on the degree of polarization between climate change-related communities, including the analysis of the linguistic features of polarized climate change-related discussions; and, b) based on the effects of the exposure to climate change-related information.

Findings: Identifying the Degree of Polarization in Climate Change-related Communities on Social Media, Including the Analysis of the Linguistic Features of These Conversations

Most of the findings revolve around measuring the degree of polarization within communicative interactions between opposing climate-change related communities on social media. Very often, these findings are contradictory: some point to users mostly interacting with like-minded individuals, while others reveal the existence of clear cross-community engagement. Among the first group, Williams et al. find that climate change-related conversations on Twitter "are characterized by strong attitude-based homophily and segregation into polarized 'sceptic' and 'activist' groups" (2015, p. 1). Similarly, Helmouth et al. (2016) show that such Twitter-based discussions mirror political affiliations, inducing polarization—e.g. that U.S. Senate Democrats and Republicans belong to two distinct and semi-isolated subnetworks here. More recently, Al-Rawi et al.'s (2021) study of the term "fake news" in the climate change discourse on social media reveals a clearly polarized debate, wherein a conservative, "skeptic" community is shown to be more engaged with the conversation than is a liberal, "believer" one. Similarly, Cann et al.'s (2021) analysis of information-sharing about climate change on social media shows that it is both polarized and politicized.

Alternatively, Chen et al.'s (2021) study of the Finnish Twittersphere reveals that climate politics are not particularly polarized in this space, although the authors also point to a significant role being played by partisanship in the molding of users' beliefs. As for YouTube, the analysis by Röchert et al. (2020) find that comments on a climate change-related video have a higher likelihood of becoming connected to ideologically opposed comments than to ideologically aligned ones, revealing a moderate opinion-based heterogeneity. More generally, Diehl et al.'s (2021) research shows that an increase in news consumption via social media leads to a decrease in the gap between left and right, suggesting that these platforms have the potential to bring groups from disparate sides of the debate closer together. Be that as it may, a recurrent finding across most of these studies,

one actually in line with the results presented in Figure 2 above, is that ideology and political affiliation are key to explaining the dissimilar degree of polarization in climate change-related conversations on social media.

There also exists a set of findings which concentrate on the deliberative nature of social media conversations as well as on the topics that they embrace. Concerning the first of these, Mo Jang and Hart's (2015) early analysis of the climate change-related communication of users in the US who, respectively, accept or question the phenomenon's existence illustrates that hoax frames that call into doubt the reality of climate change are deployed more in "red states" than in "blue states." Along similar lines, Brüggemann et al.'s (2020) examination of the climate change discourse on social media reveals that hoaxes are a salient feature of online debates. These discourses engage with contrarian voices in mutual accusations, solidifying the exclusive identities of both groups and exacerbating polarization. Furthermore, Tyagi et al.'s (2020a) quantification of hostile communication regarding the anthropogenic causes of climate change on Twitter between believers and disbelievers shows that the latter's words mostly focus on attacking influencers who do believe in it. Conversely, a study of climate change-related discussions on Twitter by Anderson and Huntington (2017) shows that instances of incivility and sarcasm are modest in these discussions overall, and that incivility is often associated instead with the discussion of political topics.

As for topics featuring in climate change-related conversations on social media, Pearce et al.'s (2014) research of the 2013 IPCC Working Group 1 report finds that most conversations studied revolve around science, geographical location, and social issues connected to climate change. Furthermore, their study reveals that most users interact with others holding similar climate change-related views to themselves. On the other hand, Arlt et al.'s (2019) analysis of the Twitter communities respectively supporting and opposing the Swiss "Nuclear Withdrawal Initiative" points to an active exchange of opinions across camps and reveals the existence of different prevailing topics within the conversations of each. Adding to this topical diversity, Meza et al.'s (2018, p. 1,075) investigation of the comments posted on YouTube about the documentary Before the Flood reveal that most of them concentrate on humorous aspects, on correcting other users' facts on climate change, and on discussing the latter's mitigation. More recently, Marlow et al.'s (2021) study of bots' Twitter activity shows that they amplify denialist messages about climate change by sharing news links on highly controversial topics, such as the announcement of US President Donald Trump's withdrawal from the Paris Agreement.

Findings Concerning the Effects of the Exposure to Climate Change-related Information on Social Media

As previously mentioned, the findings of this second set of studies revolve around the impact of climate change-related information shared via social media on: (a) individual beliefs; (b) people's engagement with related climate-related topics on social media; and, (c) users' deliberative communication practices on social media. Among the first set, Samantray and Pin's (2019) assessment of Twitter conversations about climate change (2007–2017) finds that, over time, the evolution of homophily therein reduces polarization. In other words, there is a negative association between homophily, the tendency of people to communicate with others holding similar beliefs to oneself, and polarization. Furthermore, Diehl et al.'s (2021) evaluation of the effects of news consumption via social media on people's climate change-related beliefs shows that using these platforms for news is associated with a decrease in climate skepticism, thereby helping to bridge the ideological divide between skeptics and believers here.

As for the studies on individuals' engagement with climate change-related information on social media, Chapman et al.'s (2016) investigation of user responses to photographic climate change-related material shared on social media shows that images of "solutions" are less polarizing for skeptics. Moreover, Jennings et al.'s (2021) study of U.S. Democrats and Republicans' reactions to environmental information distributed via social media finds that video messages are more persuasive and of greater utility for the former than they are for the latter. Lastly, with regard to the impact on individuals' climate change-related deliberative communication practices on social media, Shapiro and Park's (2018) examination of YouTube videos' potential to facilitate political deliberation concludes that the platform's discussion networks are not viable outlets for balanced political dialogue because, according to the authors, the debate here is driven by small groups of individuals who, at least half of the time, are running their own campaigns for or against climate change. Alternatively, Serrano-Contreras et al.'s (2020) study of participation in YouTube climate change-related videos does not reveal any "significant relationships suggesting that increased participation leads to increased polarization" (2020, p. 69).

Overall and regarding a general pattern, the findings are inconclusive, with some studies pointing to intensely polarized forms of digital communication and others revealing some degree of cross-community interaction. As for the linguistic features and the topics addressed in the climate change-related conversations happening online, hoax frames seem to be more present in the communication of disbelievers than they are in that of believers, while both communities seem to build their focus around different thematic considerations. Lastly, with regard to the effects of exposure to climate change-related information on social media, some studies show that these online

platforms can help bridge the gap between believers and disbelievers, while others are more skeptical about their potential of social media to facilitate genuine debate between the respective camps.

Table 1 provides a comprehensive overview of the studies examining the presence of polarized climate change-related communications. Specifically, it reveals that 13 identify instances of polarization, 6 report none, and 8 remain inconclusive. Despite these disparities, a discernible correlation emerges when examining the studies' thematic focus and the observed existence of polarization. Specifically, within the realm of "Communicative Interactions", 12 out of 19 studies point towards instances of polarized climate change-related communications. In contrast, only 1 out of 8 studies exploring the "Effects of Exposure to Climate-Change-related Information" identifies such polarization. Notably, within the latter category, half of the studies (n = 4) present inconclusive results regarding the existence of polarized climate change-related communications, with 3 studies reporting no discernible polarization.

On the Relationship between Different Types of Data and the Existence of Polarized Climate Change-related Communications on Social Media

In line with Terren and Borge's (2020) analysis, we assessed the potential relationship between the type of data used in the studies employed in our systematic literature review and the studies' findings with regard to the existence of polarized climate change-related communications. As shown in Table 1, our results reveal that, out of the 21 studies employing digital trace data, 12 reveal some instances of polarized climate change-related discussions, 5 indicate the presence of any instance, and 4 are inconclusive. As for the studies using self-reported data (N= 6), 2 find instances of polarization, 1 none, and 3 are inconclusive. Therefore, a slight yet clear relationship can be established between the type of data used in these publications and the studies' findings with regard to the existence of polarized climate change-related communications.

On the Relationship between Different Forms of Political Polarization and the Existence of Polarized Climate Change-related Communications on Social Media

Finally, we assessed whether there was any relationship between different forms of political polarization and the existence of polarized climate change-related communications. To do so, we read and classified the studies into the type of polarization we estimated they were focusing on. In doing so, we found that the publications of our systematic literature could be classified as focusing on ideological polarization—the divergence of political opinions, beliefs, attitudes, and stances of political adversaries (Dalton, 1987)— affective polarization —i.e. the extent to which people like (or feel warmth towards) their political allies and dislike (or feel lack of warmth towards) their political opponents (Iyengar, Sood, & Lelkes, 2012)— and elite polarization, that is, the polarization of political elites (Robinson & Mullinix, 2016).

As shown in **Table 1**, of the 27 publications included in our systematic literature review, 13 are identified as studying ideological polarization, 12 as studying affective polarization and 2, Shapiro and Park (2018) and Meza et al., (2018) studies on YouTube elite's influence on mobilizing climate change-related polarized communication, as "elite polarization". Among the publications identified as approaching ideological polarization, 5 studies reveal some instances of polarized climate change-related communications, 4 do not find any of these instances, and another 4 are inconclusive. On the other hand, with regard to the 12 publications identified as approaching affective polarization, 9 of these publications show instances of polarization, 2 indicate none and 1 is inconclusive. Similarly, the two publications identified as studying elite polarization are also inconclusive with regard to the existence of polarized climate change-related communications.

In sum, for those publications studied in this systematic literature review, there seem to be clear relationships between the type of political polarization analyzed in the publications and their findings with regard to the existence of polarized climate change-related communications. More specifically, most of the publications identified as approaching affective polarization reveal instances of polarized climate change-related communication on social media, while most of the publications approaching ideological polarization either do not find instances of polarization or the findings are inconclusive.

DISCUSSION

In this article, we have offered what, to the best of our knowledge, is the first systematic literature review on social media, political polarization, and climate change. The relatively low number of studies included in our review (n=27) suggests that the field is still a nascent one. However, the growing number of articles published in recent years suggests interest in the topic is rapidly increasing.

Similar to Terren and Borge's (2020) systematic literature review of studies on social media and echo

chambers, we found that most of our 27 studies (19 out of 27) focus on communicative interactions within and between climate change-related communities on social media; a handful of them (6 out of 27), contrariwise, assess the effects of exposure to climate change-related information on such platforms. Most of the analyzed studies also start from the assumption that polarization exists in social media discussions about climate change, which suggests that the literature has by now moved beyond seeking to prove the reality of such a schism. Indeed, the majority of these studies attempt to address the degree of such polarization and the linguistic features of the ensuing online exchange.

As for the social media platforms analyzed, there seems to be a clear focus on Twitter, with others (e.g. Facebook and YouTube) receiving significantly less attention. This is in line with the results of prior reviews on the use of social media in general (Aichner et al., 2021), and on social media and political polarization in particular (Kubin & Sikorski, 2021). Cross-platform studies are essentially nonexistent, which undermines the possibility of making any (empirically-based) general claims about the state of climate change-related polarization on social media. This is certainly a knowledge gap that future research should consider rectifying.

Relatedly, and despite the well-researched consequences that the affordances of social media platforms have on users' interactions (Bucher & Helmond, 2018), only a small number of studies included in this systematic literature review address the potential impact of platform-specific characteristics on polarizing climate change-related communication. Shapiro and Park's (2018) analysis of YouTube's facilitating of deliberative communication regarding climate change is one example here. We believe future research should study the impact that social media platforms' properties can have on polarizing climate change-related conversations in greater detail.

With regard to the data employed by the research output included in our systematic literature review, we found that most of the studies (n = 21) use digital trace data, while a minority of them (n = 6) employ self-reported data. Among those that use trace data, SNA and (qualitative and quantitative) content analyses are used to study the structure and content of online climate change-related communicative interactions. Among those that employ self-reported data, meanwhile, surveys lead as a method for data collection and statistical analyses are the dominant means of analysis. We could not find, however, any work analyzing both digital trace- and self-reported data. The significant potential arising from combining these two kinds of data should be taken into account in future studies. This could help overcome potential bias in both approaches (e.g. lack of information on individuals in the case of digital trace data and inaccuracies in self-reported data). It could also contribute to the improved study of both the characteristics of climate change-related interactions on social media and their effects on individuals, enabling a more thorough understanding of these complex issues. Stier et al.'s (2020) special issue on integrating survey and digital trace data can be of help here.

The studies included in our systematic literature review yield conflicting results about the level of climate change-related polarization on social media, with some–13 out of 27 publications, as shown in Table 1– pointing to a high degree thereof (e.g. Pearce et al., 2014; Williams et al., 2015), whereas others (n = 6) either reveal the existence of cross-community interaction (e.g. Arlt et al., 2019; Röchert et al., 2020) or are inconclusive in this respect (n = 8). Despite this divergence in the studies' findings with regard to the existence of polarized climate change-related communications, our analysis points to clear relationships between the existence of such polarized communications and the foci of the publications, the types of data used in the studies, and the different forms of political polarization approached in the papers. As can be seen in **Figure 4**, the existence of polarized climate change-related discussions on social media clearly dominates the studies focusing on communicative interactions, employing digital trace data, and approaching affective polarization. Regarding the publications focused on the effects of exposure to climate change-related information on social media, where self-reported data is employed and ideological polarization is investigated, the dominant trend is either the absence of polarization or the presence of inconclusive results.

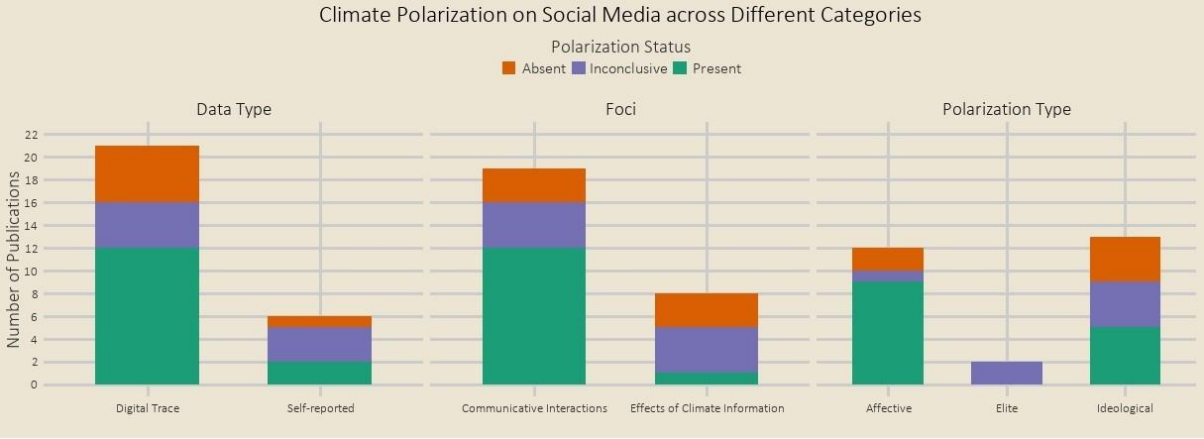

Figure 4. Visualization of the Relationship between the Publications' Type of Data, Foci, and Forms of Polarization with the Existence of Polarized Climate Change-related Communications

Since most of the relevant studies analyzed in this review were conducted in the context of the U.S. bipartisan political system, where climate change is well-established as a highly contentious issue dividing Democrats and Republicans, future research should investigate whether ideology and political affiliation are also key to explaining polarization in climate change-related communication on social media in other two-party or multiparty systems—or, alternatively, whether there are supplementary factors that can better explain this schism.

Furthermore, our research focuses on a specific period when access to Twitter data was relatively easy. However, this landscape has changed dramatically following Elon Musk's acquisition of the company, particularly affecting researchers with limited financial resources. In light of this, we plan to conduct a systematic literature review in the coming years to assess the impact of these changes on research in this field. This will not only address the platforms studied but also explore shifts in research methods and data access, as our current review suggests an interconnection between these elements.

Although the study of climate change-related polarization on social media is still in its infancy, through this systematic literature review, we have been able to identify similarities and differences between studies already in existence. This allows us to paint a critical yet eloquent picture of the peer-reviewed research done to date. Hopefully, our review provides some cohesion to a still rather fragmented field, thereby inspiring future research on such a timely topic. We particularly encourage scholars to expand our current understanding of events on social media by combining theoretical domains (e.g. environmental and media ones) and methodological approaches (e.g. SNAs and surveys). Doing so could produce more nuanced insight into the multifaceted nature of this climate change-related polarization currently playing out online.

CONCLUSION

This systematic literature review has outlined the findings of a content analysis involving 27 peer-reviewed scientific articles on social media, political polarization and climate change. It has revealed that most of the studies (a) focus on communicative interactions within and between climate change-related communities on social media, (b) specifically target Twitter, (c) employ digital trace data, and (d) yield contradictory results with regard to degree of climate change-related polarization on social media.

Despite the publications' divergent results concerning the existence of political polarization, our paper points to a clear relationship between the studies' foci, type of data, and forms of polarization. Specifically, polarized discussions on social media concerning climate change clearly overshadow studies that explore communicative interactions, utilize digital trace data, and address affective polarization. Alternatively, in publications investigating the effects of exposure to climate change-related information on social media, and particularly those relying on self-reported data to examine ideological polarization, the predominant trend is either the absence of polarization or inconclusive results.

Our systematic literature review has also identified potential avenues for future research. First, there is a clear need for cross-platform investigations. Second, much remains to be understood about the impact that the affordances of social media platforms can exert on polarizing climate change-related conversations. Third, future studies should seek innovative methodological approaches to integrate digital-trace data and self-reported data.

Overall, and despite its limitations, this systematic literature review contributes a unique taxonomy of studies on social media, polarization and climate change. This offers a valuable starting point for future works to advance our understanding of polarized climate change-related conversations.

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APPENDIX

Appendix 1

The full list of the 27 peer-reviewed publications, including authors, titles, journals, year of publication, databases, and data types, can be accessed via: https://osf.io/n7s9w/?view_only=fb84b3a3615c44988a2ef770c1da0372

Appendix 2

As mentioned above, we used Boolean searches including exclusively the following keywords: "social media" AND "polarization" AND "climate change." This was a topic search identifying correspondence based on titles, abstracts, and keywords. We also employed a Boolean search in the database Web of Science with the keywords "social networks" AND "polarization" AND "climate change." This search returned eight articles. Of these, five tackled offline social networks exclusively, two were already included in the works yielded by our initial Boolean search, and one was a review of the literature. Consequently, we decided to use the Boolean search "social media" AND "polarization" AND "climate change."

The list of the eight peer-reviewed publications, including authors, titles, journal, year of publication, databases, and types of study, can be accessed via: https://osf.io/n7s9w/?view_only=fb84b3a3615c44988a2ef770c1da0372

Future research should consider increasing the number of keywords employed in our study to enhance the collection of data regarding the subject.

Appendix 3

The list of the 25 discarded publications, including authors, titles, journals, year of publication, databases, and excluding rationale, can be accessed via: https://osf.io/n7s9w/?view_only=fb84b3a3615c44988a2ef770c1da0372

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