Experts, influencers, and amplifiers — Exploring climate movements' hyperlinking practices

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Abstract

While research shows different links between activism and science, little is known about activists engaging in science communication online. Demanding that decision-makers should "listen to the scientists", the climate movements Fridays for Future (FFF) and Extinction Rebellion (XR) emphasize the role of scientific knowledge in democratic decision-making. Exploring the two movements' hyperlinking practices reveals a difference in the extent and selection of hyperlinks on their websites, pointing to influencer-based communication and focus on popularization of science by FFF and expert-based communication leaning on academic publications by XR, with both movements acting as amplifiers of existing science communication efforts.

Keywords

Environmental communication; Public engagement with science and technology; Public perception of science and technology

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Introduction

In 2018, two new climate movements emerged in Europe: the "Fridays for Future" (FFF) student protests initiated by Swedish high school student Greta Thunberg and the "Extinction Rebellion" (XR) civil disobedience protests originating in the UK. Both movements lean heavily on climate science, arguing that "the science is clear" [Extinction Rebellion UK, n.d.] and that policymakers should "listen to the scientists" [Fridays for Future, n.d.(c)]. The groups' use of digital and social media in combination with other protests has created much visibility online and in traditional media, both for the issue of climate change and for scientific studies thereof. This makes the movements interesting examples of activists as science communicators. Their almost zealous and in parts defensive, in parts idealized support of science in general and climate science in particular provokes questions on how the activists connect their demands to scientific knowledge production, and which sources and formats of scientific information they refer to and in turn make visible to their audiences. In this paper, I therefore explore the websites and hyperlinking practices of the FFF and XR movements to examine their role in communicating and amplifying scientific knowledge on the topic of climate change.

Two new climate movements

Fridays for Future originated in August 2018 with the Swedish teenager Greta Thunberg going on a weekly "school strike" to demand climate action from the Swedish parliament. Other students joined, and the movement soon spread beyond Sweden. Students are joining protests and demonstrations on Fridays instead of attending school, pointing to the discrepancy between learning information about climate change in school and the lack of political action to reach agreed-upon climate goals. The movement is organized loosely on an international level and argues that it is the role of politicians and experts to figure out exactly what change is needed, refraining from commenting on policy themselves. The group's demands are: "1. Keep the global temperature rise below 1.5°C compared to pre-industrial levels. 2. Ensure climate justice and equity. 3. Listen to the best united science currently available." [Fridays for Future, n.d.(b)].

Extinction Rebellion originated in the United Kingdom in May 2018. The group uses nonviolent forms of protest. It received international media attention for elaborately orchestrated and highly visible acts of civil disobedience, for example blocking infrastructure or staging "die-ins" to point to issues of biodiversity loss, social injustices in relation to climate change, and the dangers associated with greenhouse gas emissions. Their demands are: "1. Tell The Truth — Government must tell the truth by declaring a climate and ecological emergency, working with other institutions to communicate the urgency for change. 2. Act Now — Government must act now to halt biodiversity loss and reduce greenhouse gas emissions to net zero by 2025. 3. Beyond Politics — Government must create and be led by the decisions of a Citizens' Assembly on climate and ecological justice." [Extinction Rebellion, n.d.].

The two movements were initially chosen for their similarities with an intention of comparing their practices. Both are European, both were established in 2018, both work with global online as well as local real-life activities, both emphasize science to establish the extent, urgency, and legitimacy of the issues they seek to address, and both see democratic decision-making processes as the most important lever to solving them. Both movements have received increased media attention especially throughout 2019, have gathered an international following on social media, and have managed to organize protests and demonstrations across Europe and the world. Both groups have sparked interest among researchers, for questions on studying these movements [e.g. Bevan, Colley and Workman, 2020; de Moor et al., 2020; Feldman, 2020] as well as questions on whether and how scientists should relate to the movements' demands [e.g. Fraser, 2019; Hagedorn et al., 2019; Mahase, 2019; Mitchell, Rub and Wainwright, 2019; Shah, 2019]. Besides visible engagement with the topic in both mass media as well as scientific outlets, statements of support and scientist-led initiatives such as "Scientists for Future" and "Scientists for Extinction Rebellion" show the close connections to academia the two movements have built. They have in common that they have contributed to current narratives on climate change, providing narratives with a bigger sense of urgency [Bevan, Colley and Workman, 2020]. Both have managed to engage new participant groups in disobedience for political activism (although both are biased towards a more educated part of the population), and both have targeted local and national governments with their activism and the framing of 'listen to the science' [de Moor et al., 2020].

At a closer look, however, the groups reveal distinct characteristics, too. They differ in demographics with much younger participants in the FFF student protests. They use different modes of peaceful protest with XR emphasizing highly noticeable acts of civil disobedience to gain media attention and FFF using more traditional protest rallies and school strikes. And finally, the groups differ slightly in their messaging with XR adding the concern of biodiversity loss to the shared concern of climate change.

Activism and science communication

Horst et al. define science communication as "organized, explicit, and intended actions that aim to communicate scientific knowledge, methodology, processes or practices in settings where non-scientists are a recognized part of the audiences" [Horst, Davies and Irwin, 2016, p. 883]. In environments of "post-normal science communication" where boundaries between journalism and science are increasingly blurry [Brüggemann, Lörcher and Walter, 2020], activism emerges as one of many "alternative" [Maeseele, 2009] actors in science communication activities. These activities are no longer limited to scientists themselves or formal science communication practices within science journalism or science education. While activists' use of science for their own sense-making [Fähnrich, 2018] and their potential role as knowledge-brokers in policy-making processes [Sardo and Weitkamp, 2017] have been explored, their role in public communication of environmental science has only recently come under scrutiny [Faehnrich, Riedlinger and Weitkamp, 2020; Feldman, 2020; Gregory, 2020; Rödder, 2020; Windfeldt, 2020]. NGOs working with environmental issues and environmental action groups can be especially prone to take on a role in communicating scientific information "because empirical claims about the state of the natural environment are core to their message" [Yearley, 2008, pp. 168–169], making them an interesting subject for studying alternative forms of science communication.

Considerations of alliances and blurry lines between science and activism are not new, for example with activists and patient organizations demanding and succeeding to gain influence over the scientific study of diseases [e.g. Epstein, 1996] as "emergent concerned groups" [Callon and Rabeharisoa, 2007]. Similarly, grassroots citizen science or civic science movements have emerged around the topic of pollution [e.g. Ottinger, 2010], aligning themselves with selected scientific practices and practitioners to challenge standards and influence decision-makers. In exploring the roles of activists as science communicators, local NGOs acting as "alternative science communicators" have been described as working to reframe or contest the "science-industrial complex" [Maeseele, 2009] and aligning with some parts of scientific knowledge production processes in order to challenge others. While similar forms of alliances between concerned groups and scientists exist in various constellations, XR and FFF present an interesting case in their emergence from and support of academic scientists. In contrast to an initial challenge of academic standards or practices as seen in other groups that successfully mobilize connections between scientists and activists, XR and FFF fully embrace and promote established scientific knowledge.

Their close alignment with science and especially climate science also raises questions on the involvement of researchers in these movements within the

scientific community at large. Pielke Jr. [2007] describes four idealized roles that scientists can take on in relation to politics (pure scientist, science arbiter, issue advocate, honest broker). While he sees all four as legitimate options depending on circumstances, he warns against taking on a role as a "stealth issue advocate" politicizing science. Climate scientists and other natural scientists increasingly find themselves facing a decision of whether or not they should join more radical climate movements demanding political changes — and whether 'radical' is actually a fitting term for describing them [Fraser, 2019; Shah, 2019]. Statements of support are being offered by academic communities, groups of scientists are publicly joining the movement [Hagedorn et al., 2019; Mahase, 2019], and supporting activist groups named "Scientists for Future" and "Scientists for Extinction Rebellion" have been formed. This indicates an increasing overlap between activists, science communicators, and scientists, with some individuals taking on different roles in different contexts. Interestingly, in this case the ties between activism and science are not motivated by outsiders' challenges but by widespread support for political demands based on climate science from both within and outside of academic communities, inviting a closer examination of the new climate movements' communication practices.

Social movements online

Social movements aiming to influence political decision-making are increasingly relying on new communication technologies, in particular social media platforms, to organize themselves, to recruit new members, and to reach large audiences with their demands. Events with widespread social media activity, such as the Arab spring protests in 2011 or the viral spread of the #MeToo hashtag in 2017, have received attention both from the public and from scholars.

Social media platforms allow for "heterogeneous couplings" between scientific and nonscientific actors, objects, and interactions [Costas, Rijcke and Marres, 2020], not formally distinguishing between elements of different form, origin, or content and allowing users to seamlessly move between them. Similarly, hyperlinks can point to different types of contents and resources, and, despite a general turn to platforms, still offer valuable insights for social science research since they can move beyond the 'gated communities' of platforms [Ooghe-Tabanou et al., 2018]. However, what users do with this potential for heterogeneity across form, source, and content, can differ vastly between online spaces. An analysis of comments on two English-speaking climate blogs showed that commentators only engaged within like-minded groups and focused on one-way communication [Metcalfe, 2020]. In an analysis of German climate change discussions online, generalization across different spaces proved difficult, revealing the presence of various "online public arenas" with overlapping but distinctly different interests and commenting practices [Lörcher and Taddicken, 2017].

Despite the growing interest in these types of online interactions, there is surprisingly little research on the use of digital information and communication technologies in activist movements for sustainability or environmental issues, as well as related online communities. In part, this might be due to some of these movements' extreme focus on the local [Kenis and Mathijs, 2014]. In research on agricultural practices, Vallauri [2014] concludes that online communities might

enhance but not replace communal activities and quotes a website coordinator who wants participants "to switch off their laptops and come meet us in the neighbourhood!" Nevertheless, newer climate movements such as FFF and XR in Europe or 350.org in the U.S.A. increasingly rely on digital media to coordinate and communicate their efforts. While the movements have received some attention in the academic literature [Bevan, Colley and Workman, 2020; de Moor et al., 2020; Mitchell, Rub and Wainwright, 2019], their online presences have, despite being an important part of the movements' abilities to gain public attention, not yet been explored as part of their science communication activities.

Aim and research questions

Both FFF and XR engage in discussions about climate science as well as the role of scientific knowledge in democratic decision-making. Together with their highly visible online activities, this makes them interesting examples of alternative science communicators in online settings. The aim of this paper is to contribute to a better understanding of the two groups' activities in the context of online science communication and to examine what sources these groups refer to as 'the science' emphasized in their demands. By exploring the online communication activities on the websites of both XR and FFF, I want to answer the following research questions:

1. What is the role of scientific information on the movements' websites?
2. How do the movements make use of existing forms of science communication?
3. How do the movements act as alternative science communicators?

Methods

Costas, Rijcke and Marres [2020] describe how social media platforms allow heterogeneous couplings between scientific and nonscientific actors, objects, and interactions. Similarly, hyperlinks remain an important part of web infrastructure even in the age of social media platforms [Ooghe-Tabanou et al., 2018]. They can point to different types of content online, allowing the curation of collections that refer to a wide variety of media formats, sources, and topics and making these available to other users. As climate movements create such collections of hyperlinks related to climate science on their websites, they build on a variety of existing formats and sources of science communication, selecting, assembling, and amplifying them to build their own communication strategy. To analyze the role and types of references to science used by XR and FFF, I have conducted a website analysis and a detailed analysis of hyperlinks found on the movements' websites as described below. All data was collected on 2020-09-09 and analyzed in the weeks thereafter, with some additional analysis conducted on the collected materials in August 2021.

Website analysis

To examine the referencing practices of new European climate movements, I explored the websites of the two movements 'Fridays for Future' (FFF) and

Table 1. Number of hyperlinks by website sections

Page sections	FFF	XR UK
contact information	400	290
events	135	
resources for members	7	208
about	18	29
issue — climate & biodiversity	7	871
issue — democracy		31
issue — finances		30
Total hyperlinks	**567**	**1459**

'Extinction Rebellion' (XR).[1] After examining the overall structure and appearance of the websites, I extracted xml sitemaps to get an overview of the sites' pages and contained hyperlinks. These were then used to identify sections of the websites that contain more static content (as opposed to sections with frequent changes such as news or press releases) to capture core interests of the movements rather than short-lived campaigns or news items. In addition to the version of the websites scraped for hyperlinks, I explored the history of both websites using the Internet Archive Wayback Machine[2] to examine the development of the pages over time and to verify that the selected static website sections indeed remain stable over a longer time.

The central websites of the two examined climate movements only present a small glimpse into their online activities. For both XR and FFF, the websites serve as a hub to link to resources, ongoing events and campaigns, and most importantly contact information for local groups. Dynamic content on these websites, the change of the sites over time, content of social media activities, and content of local accounts or prominent supporters also are a large part of the movements' online activities. This study was limited to an analysis of more static website content to capture core science communication activities of the movements that remain more stable over time, rather than more dynamic social media content or news or event pages with frequent changes. Neither the reasons behind the selection of certain links nor the sites' policies of content creation were explored as part of this study, focusing instead on the results of activist movements' science communication practices as they are visible online to both human and machine (e.g. search engine crawlers) visitors of the websites.

Hyperlink analysis

After mapping the structure of both websites, I used the DMI link ripper[3] tool to harvest all hyperlinks from selected static content sections of the websites, collecting a total of 2026 hyperlinks. Table 1 shows an overview of the website sections with corresponding numbers of hyperlinks.

[1] Initially, the international websites (fridaysforfuture.org, rebellion.global) were considered; however, with more content and being the starting point of the movement, the UK website for XR (now extinctionrebellion.uk, previously rebellion.earth) was used for the study.

[2] https://archive.org/web/web.php.

[3] https://wiki.digitalmethods.net/Dmi/ToolLinkRipper.

I then explored the hyperlinks in detail, following a 'haystack to needle' approach [Hagen and Jokubauskaitė, 2020], considering and categorizing all domain names captured in the dataset instead of searching for known sources or relying on URL-names alone, in order to get a detailed picture of the content linked to by the two movements. I manually examined all collected links for the source (i.e., the person or organization providing the content), the media format, and the topic of linked webpages. When encountering broken links, I tried to find archived versions using the Internet Archive Wayback Machine.

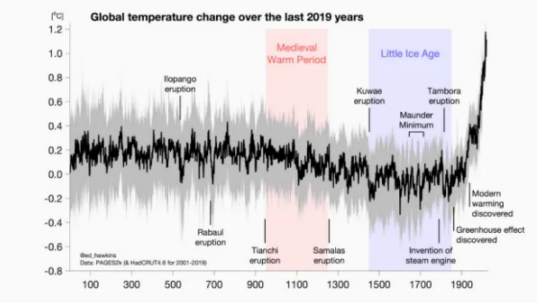
Subsequently, I grouped all links into categories in an inductive and iterative process considering sources, formats, and topics. I grouped the different formats into three overarching media types: text dissemination, multimedia dissemination, and interactive media. Since there was a significant overlap between the categories of formats and sources (e.g., most academic texts stem from academic sources), I chose to report the most frequently named individual sources instead of the categorizations. Additionally, six topics emerged from the categorization of links.

Duplicates were not removed from the results since they did not occur at a significant rate. However, some sources such as IPCC reports are cited more than once, and some sources were linked in different formats (e.g., a pdf document and a landing page for the same report, or a press release and the article page for the same scientific publication). Not removing these duplicates presents the weight of the hyperlinks as used on the page, results might differ slightly if only checking for unique content linked.

Results

The Fridays for Future and Extinction Rebellion websites are similar and fulfill similar functions. For both Fridays for Future and Extinction Rebellion, the websites serve as a hub to point to resources, to link to social media accounts from global and local accounts, and to invite visitors to join national and local groups. While the movements overall are present on many different social media platforms, the smaller subgroups often use only one or a smaller selection of platforms, and do not necessarily have websites on their own, making the overarching international websites a key point of reference for them as well. Both groups offer information about the movement and their demands and provide materials to engage with politicians locally or start own branches of the movements and both offer scientific background information on climate change, although the amount, sources, and formats differ distinctly. The two groups' websites are similar in their structure and visual appearance. The contact pages of both websites are among those with the largest amounts of hyperlinks. Many of the links in the contacts, events, and resources sections lead to social media platforms or pages internal to each group. They indicate the strong emphasis on local subgroups for both XR and FFF. Both movements also link up with dedicated partner movements by scientists (Scientists for Future and Scientists for Extinction Rebellion). Table 1 above shows a detailed overview of the websites' structures and number of hyperlinks contained in each section.

The analysis of older versions of each website reveals that XR used a professional-looking web design from the start and gave detailed scientific information on a page labeled "the emergency" that was eventually split into several pages in the version of the website analyzed here. While the XR page has



Source:
https://www.climate-lab-book.ac.uk

Each of the last three decades has been successively hotter than the one before, 19 of the top 20 hottest years have occurred in the last 19 years, and the past four years have been the hottest on record. 2016 was the hottest year ever recorded, whilst in 2019, nearly 400 temperature records were broken across 29 countries, June 2019 was the hottest on record, and July 2019 was the hottest month ever recorded. As of July 2020, January 2020 was the warmest January ever recorded in Europe, we saw the hottest May ever and we already have an 85% chance that 2020 will turn out to be the hottest year on record.

Figure 1. Part of the XR website archived at ttps://web.archive.org/web/20200919230926/https://ex truth/the-emergency/part-1/.

seen only slight changes and mainly additions to its content, the FFF website started out less structured and looking less professionally edited, with content spread out across different subpages and a menu-item called "more" containing much of the information through several layers of subpages. The navigation and layout of the page was changed completely from the original version to the version analyzed here, offering a more easily navigable menu structure with a section on "reasons to strike" similar to the "the emergency" section of the XR website. The following analysis refers to the websites at the time of data collection (September 2020).

The role of scientific information on the climate movements' websites

Notably, the XR website contains almost 900 links on their pages related to climate change and biodiversity loss, pointing to scientific evidence for the movements' claims about the issues at stake and their urgency. These pages contain a lot of information, texts, graphs, and hyperlinks to sources about the issue of global warming, stating that "the science is clear" and quoting scientists and internationally known authority figures. Websites of national groups can be found through a map of "branches" in different parts of the world, and provide more content in other languages, still following the same design and similar structure as that of the main website, showing a structured organization and close links between the original group and local branches. The group demands the creation of citizen assemblies for democratic decision-making to curb the effects of global climate change [Extinction Rebellion, n.d.] and uses their website to expand on these demands and provide detailed background information on the issue. Large parts of the website contain graphs and long text elements with hyperlinks connected to sections in the text as a form of referencing (see Figure 1 for an example).

For FFF, the substantial number of contact information links indicates that the main

Figure 2. Part of the FFF website archived at https://web.archive.org/web/20200919152312/https://fridaysforfuture.org/take-action/reasons-to-strike/.

purpose of the website seems to be pointing visitors to relevant local subgroups. The website contains a prominently displayed large table of contact information and social media links to various subgroups in different countries. Fridays for Future also provides a lot of information in video format, and publishes speeches held by young climate activists including Greta Thunberg. The websites of national initiatives linked here have unique designs and structures, pointing to more independent, loosely connected groups in the different countries. In their frequently asked questions, the organization states "Fridays for Future does not have the capacity or the competence to evaluate solutions. If you have a solution, we therefore urge you to send your contribution to those who do, so that it can be put to use" [Fridays for Future, n.d.(a)] implying a responsibility of local, national and international policymakers and decisionmakers for evaluating and implementing solutions to climate change. Figure 2 shows an example of a collection of links from the FFF website.

Forms of science communication accessed and shared by the climate movements

The hyperlinks collected from the two climate movements' websites point to a wide range of different online resources. These were categorized for their affiliation with various sources, their media formats, and the topics they contained.

Sources referred to

Both XR and FFF refer to a wide variety of sources. Appendix A contains a list of the most frequently referenced domain names by each organization. For XR, 28 domain names linked 10 or more times account for 62% of all outgoing hyperlinks. For FFF, 6 domain names linked 10 or more times account for 86% of all hyperlinks. This shows a higher concentration of links towards fewer sources for FFF, where social media platforms, e-mail addresses, YouTube videos, and references to the own website make up the bulk of all collected links, the main part of which refer visitors to local subgroups of the movement. XR, in addition to social media and

e-mail links, refers to a wide variety of sources including news websites, academic publishers and journals, popular (climate) science outlets, and many more, with many sources referenced only a few times.

Of the links not used for contact information purposes, for FFF, many links go to social media platforms and videos where categorizing the source is challenging. Many can be summarized as leading to "influencers", with talks and presentations about climate change e.g., by Naomi Klein, a playlist of speeches by Greta Thunberg and other young climate activists, as well as popular science representations such as a video "Climate Science: what You Need To Know" produced for publication on YouTube by American public broadcaster PBS. Other sources include other activist movements and NGOs. One link goes to the climate section on the NASA website.

For XR, the picture is different, both in the much larger number of links to scientific information and the type of sources used overall: links to e-mail addresses and Facebook as well as XR's own website are occurring frequently, linking users to local groups and resources of the movement. However, substantial amounts of links also point to academic sources such as academic journals or publishers. Additionally, links to governmental and large intergovernmental organizations, for example the UN and its different organs, national governments, or national offices and ministries occur frequently. Other sources include organizations dedicated to policymaking or research for political decision-making such as NASA and the IPCC but also think tanks and research alliances. One group of links points to various news organizations (including large international, smaller local, and special interest news organizations), organizations engaged in popular science and education (including Wikipedia, a range of blogs and education websites about climate change, museums, and popular science magazines). Finally, XR links to a small number of other activist movements and NGOs.

Formats referred to

Both FFF and XR make use of a wide range of different communication formats in the links they refer to, making full use of the heterogeneity that hyperlinks permit. Nevertheless, some formats occur more frequently than others. I have grouped the different communication formats into three broad categories: text dissemination, multimedia dissemination, and interactive media. A detailed overview of the categories and subcategories is shown in appendix B.

The group named text dissemination refers to sources that focus on information in textual format, mainly comprised of academic articles and policy reports, but also including news, education, and popular science formats if they are text-based (e.g., blog posts). This category accounts for 4% (22 links) of hyperlinks from FFF and a majority of 58% (841 links) of hyperlinks from XR. Both groups also include links to crowdsourced texts such as shared documents or wiki articles, the majority of which stem from the organizations themselves and provide materials to support activists.

Multimedia dissemination comprises video and visual content as well as social media content (e.g., individual tweets or posts) and social media collections (e.g.,

links to a tag, topic, or playlist). For FFF, 16% (90) of the outgoing hyperlinks fall under this category. For XR, it covers 18% (261) of the outgoing links.

In both text and multimedia dissemination, interactive options such as commenting or sharing functions might be available but in each case the emphasis lies on relating information to the audience. In the third category, interactive media, the emphasis moves instead to interacting with the audience or getting the audience to take action. This includes explicit requests to volunteer or donate, calls to participate in specific campaigns, e-mail addresses and forms allowing viewers to get into contact with specific parts of the movements, and links to social media profiles implicitly requesting that users follow, befriend, or share content. For FFF, this category makes up 79% (446) of all outgoing links, whereas for XR it only accounts for 22% (326) of the links.

When referring to scientific information, FF mainly links to social media platforms and audio-visual content, with many links to YouTube videos. Extensive lists of links to national groups of the organization with different e-mail addresses and social media profiles make up the majority of hyperlinks on the page, indicating a less involved or less direct approach in communicating science from their website. Few academic texts are directly linked from the FFF website and dissemination of information makes use of various multimedia formats.

For XR, the largest group of formats is academic texts (mainly published journal articles, but also including pre-prints, working papers, or detailed data-analyses), closely followed by a large number of news texts (such as news articles and blog posts). Other text formats such as various reports and briefings as well as collaboratively created documents containing resources for XR members are also linked extensively from the website. Overall, dissemination of information through text makes up a large part of hyperlinks by XR. Multimedia dissemination seems less common for XR than for FFF. XR also provides contact information and social media profiles but these interactive media formats dominate less than they do for FFF.

Topics referred to

General information about climate science, including information about emissions, temperatures, climate models, and extreme weather, is present on both XR's and FFF's websites but much more prevalent in XR's hyperlinks. For FFF, the biggest group of links leads to e-mail addresses and social media profiles, categorized as contact information. The second-biggest group of links leads to information about political action, including own and other NGOs' campaigns, requests for donation. Only few links point to information on climate science and the societal relevance of climate change and only one link refers to ecosystems. Information on ecosystems and biodiversity was almost exclusively linked to by XR. A large share of the hyperlinks by XR refer to societal issues related to climate change, such as migration or economic costs of climate change. A group of links in this category is concerned with agriculture and food, both as a threat to biodiversity if left unchecked, and a threat to humanity if disrupted. Some links lead to discussions of carbon capturing technologies that emphasize the difficulty and limited potential of such projects. Table 2 contains an overview of topics and categories linked from each site.

Table 2. Topics of sources referred from FFF and XR websites.

Topic group	Description	FFF	XR UK
[other]	*inaccessible links, rare topics*	*4*	*25*
Climate science	climate change, modelling, emissions, extreme weather events	7	371
Contact information	e-mail addresses and social media profiles of FFF and XR as well as related groups	470	337
Ecosystems	biodiversity, tipping points, water systems, ice loss	1	212
Political action	politics, sustainability transition, policy processes, activism (including supporting information for activists, own and other campaigns for climate action)	80	258
Societal relevance	Impact of/on climate change for/by society (including agriculture, food, water, health, inequalities, economy, pollution)	5	256
Total		**567**	**1459**

Notably, both XR and FFF refer mainly to the natural sciences and discussions of the issues at stake and their urgency, with few links to possible solutions (whether technical, social/behavioral, or political) or to contributions from the social sciences or humanities. Links that serve to establish the issue of climate change as relevant and urgent are more likely to go out to scientific publications (especially for XR) whereas links guiding activists on what to do frequently point to own resources or social media.

Discussion

This study compared hyperlinking practices on the websites of two European climate movements both established in 2018. Contrasting the two movements' hyperlinking practices paints a picture of two similar interest groups with overlapping goals that have chosen two different styles of communicating about the science of climate change on their websites. While the hyperlinks on XR's website present a more technical, academic, and expertise-based style of communication, FFF employs a more accessible, popular style that relies on local subgroups and figureheads as "influencers". Despite different communication styles in detail, both groups emphasize sources and topics from the natural sciences, both groups act as amplifiers of existing science communication practices, and both groups show indications of being both alternative actors as well as alternative outlets for science communication.

What is the role of scientific information on the movements' websites?

Both the FFF and XR websites contain information about climate science and the impact of climate change on social and ecological systems. And both movements emphasize the role of scientific knowledge in informing democratic decision-making in their demands. However, the role of scientific knowledge on the websites differs slightly between the two groups. For FFF, the bulk of the hyperlinks from the website refer to contact information for local subgroups in different countries and regions. The second-largest group of links contains

information on political action. A much smaller number of hyperlinks on the topics of climate science and climate change, together with the reliance on multimedia formats and well-known figures or 'influencers', indicates a more indirect science communication approach. Direct science communication efforts only make up a small part of the FFF website, the main purpose of which seems to be the collection of contact information for affiliated groups (who may be engaging in science communication as part of their online activities). The XR website also presents contact information for subgroups and information on political action, acting as a central information hub for the affiliated groups similar to the FFF website. Additionally, however, the XR website contains large numbers of hyperlinks on climate science, ecosystems, and the impact of climate change on societies, often linking directly to scientific publications or policy reports. These links occur as part of long and elaborate texts on the issues and represent a more direct science communication effort created by the group itself.

The content linked from the two movements' websites mainly refers to texts (for XR), and texts or multimedia content from authoritative sources, rather than databases, citizen science projects, or crowdsourced documents (which do occur but given the political ambitions of participation of the groups, might have been expected to play a bigger role). While links on the issue of climate change point to a range of prestigious academic sources, many links on political activism lead to other activist groups or collaborative documents by the movements. Discussions of potential ways to address climate change (technical or social), studies of existing or possible transition processes, knowledge about behavioral change, or other insights from a wider range of academic disciplines could have been underlined in a similar way by academic literature yet are largely absent from the examined websites.

Both movements provide only schematic answers to questions of which expertise should be involved in tackling global challenges, repeating the slogans of "Listen to the scientists" (FFF) and "The science is clear" (XR). Both XR and FFF refer to a generic image of "the science", that is unambiguous in the identification of the problem of climate change (along with biodiversity loss and problems of social justice) and seen as the correct group of experts to identify and characterize the problem. Interestingly, despite the movements' emphasis on 'the science', the IPCC reports considered the main source of academic consensus on climate change only feature as one of many sources with XR and are not directly linked at all by FFF. XR seem to undertake an own summary of different academic sources concerned with climate change, biodiversity loss, and the societal relevance of both on their website. FFF on the other hand refer to other forms of science communication, such as videos or training materials that in turn might reference the IPCC reports, indicating a reliance on more mediated sources of scientific information for FFF and a smaller role of this information on the website compared to XR.

Both groups demand that politicians should take the known threats seriously and plead that states should aim to reach agreed-upon climate goals. As for the expertise of evaluating potential strategies for dealing with climate change, FFF argues on their website that solutions to climate change should be evaluated by scientists giving input to established democratic decision-making processes, whereas XR pushes for the establishment of citizen assemblies to find and evaluate solutions. Neither of the two underline these approaches with further scientific evidence or claims like they do for climate science resources. Both groups attribute

expertise to a generic image of "the scientists", arguing that this is the group of experts that political decision-makers ought to listen to but remaining somewhat vague [de Moor et al., 2020]. They delegate responsibility for evaluating potential ways of addressing climate change back to experts (FFF) or a citizen assembly to be established (XR). In a (possibly intended) contrast to frequently voiced worries about 'fact-resistance' and a perceived loss of trust in science, XR and FFF present a different picture about what they think the role of scientists should be, demanding that decision-makers should recognize the established scientific consensus about threats of climate change, biodiversity loss, and social injustice. At the same time, these movements do not only communicate the content of one area of science but also about the role of science, painting an image of science as giving input to democratic decision-making processes in a perhaps oversimplified way. Considering Pielke's [2007] description of ideal types of scientists' roles in political decision-making, many of the scientists linked directly or indirectly to both movements can be seen acting as outspoken 'issue advocates' demanding to be heard whereas the representation of science on XR's and FFF's websites paints an image closer to an ideal of a 'pure scientist' providing input to others' decision-making as objective experts with little or no interest in the outcome — an idealized role difficult to argue for in the face of all-encompassing threats and urgent need of change in relation to global warming.

How do the movements make use of existing forms of science communication?

The websites of both XR and FFF can be considered a science communication effort themselves, curating and presenting information about climate science. More than that, however, they act as amplifiers linking to a variety of existing science communication efforts. In line with Yearley's [2008] description of environmental groups likely taking on roles as science communicators on the state of nature, the links to scientific information by both XR and FFF mainly cover different aspects of climate change and biodiversity loss. Both movements refer to science to establish the extent and urgency of the issue of climate change (and biodiversity loss in the case of XR) and the vast majority of hyperlinks is closely connected to academic research on these issues specifically, amplifying science communication efforts across journalism, academia, activism, and policymaking in this area.

The use of hyperlinks to scientific knowledge on the websites of FFF and XR can be summarized as two distinct styles of science communication. XR engages in a more academically oriented, expertise-based use of hyperlinks, frequently and extensively pointing to academic heavyweight sources such as publications in *Nature* or *Science* or the IPCC reports, while also contributing with a long tail of links to other academic sources. There is a much larger amount of text sources by XR than by FFF. These links are embedded in long and detailed texts on the matter created explicitly for the XR website. FFF on the other hand, refers to more accessible formats, linking to videos and social media content rather than text and using well-known figures as "influencers" to establish trust and credibility of the presented information. FFF also has a more indirect style of science communication, linking less information directly and relying on existing formats as well as local subgroups rather than creating own new communication formats on their website. These different communication styles might align with the different participant demographics of the two movements. Nevertheless, there is an overlap

in the chosen strategies as well. While FFF relies on videos of "influencers", XR also has a (text-based) section of well-known figures with links to their statements. The examined hyperlinks especially for XR lead to a vast range of formats and sources, covering a variety of academic texts and grey literature but also pointing to science communication formats that target wider audiences such as press releases, newspaper articles, videos, or webcomics.

The side-by-side use of different science communication formats and the different styles of communication by the two movements point to the value of a variety of science communication formats that alternative science communicators can access and share with wider audiences. The two movements use distinctive communication styles but both use their websites and the heterogeneity that hyperlinking allows as a way to contextualize scientific information and to amplify existing science communication formats.

How do the movements work as alternative science communicators?

The activities of XR and FFF show two ways in which scientific research links to activism: firstly, activist groups can take up science to underline their demands, acting as amplifiers for other science communication channels. And secondly, scientists themselves can turn to supporting or establishing activist movements as an outlet of their research activities outside of academia.

Close connections between XR and climate scientists, and related movements of "Scientists for Future" and "Scientists for Extinction Rebellion" referred to by both websites indicate that some academic researchers are leaving behind ideals of neutrality or objectivity in relation to political decision-making and turning activism and science communication into processes that researchers (alongside with other participants) might choose to engage with as a result of their academic work or as outspoken "issue advocates" [Pielke Jr., 2007]. Boundaries between journalism and science are increasingly blurry [Brüggemann, Lörcher and Walter, 2020]. The analysis of the two climate movements' websites shows that similarly, the boundaries between science, science communication, and activism are also blurring. The websites contain both scientific and political topics and use a variety of sources side-by-side. The heterogeneity of hyperlinks that creates the same visual appearance for links to different formats and sources may contribute to this blurring of boundaries. While XR and FFF might not necessarily consider or name their actions as science communication, they do engage in communicating (climate) science to wider audiences, showcasing how "alternative" [Faehnrich, Riedlinger and Weitkamp, 2020] actors can both make use of and share or amplify existing science communication efforts. At the same time, the movements' highly educated demographics and the engagement of climate scientists in related and supporting movements suggest that some of these activities could also be characterized as alternative outlets for, rather than actors of, science communication.

The heavy use of academic journal articles and the text format using hyperlinks as references, especially on the XR-UK website additionally hint at an academic orientation of both site creators and intended audiences. This raises questions whether boundaries between "science" and "activism" can be drawn fruitfully. While many accounts exist of activist movements successfully using science, for

example in patient organizations [Callon and Rabeharisoa, 2007; Epstein, 1996] or in citizen science projects on pollution [Ottinger, 2010], these accounts frequently see activists as outsiders challenging academic research who eventually gain access and influence in both scientific and political dimensions. XR and FFF on the other hand show close ties to academic communities and extensive efforts to communicate and promote the use of science in political decision-making.

Seen together with indications that these movements have successfully contributed to strategic narratives aimed at increasing support for policy measures to address climate change [Bevan, Colley and Workman, 2020], this points to a strong role of activists as science communicators as also indicated by a series of comments [Faehnrich, Riedlinger and Weitkamp, 2020; Feldman, 2020; Gregory, 2020; Rödder, 2020; Windfeldt, 2020].

Conclusion

In this study, I have explored the websites and the use of hyperlinks by Fridays for Future and Extinction Rebellion. The two climate movements' online activities lie at an intersection of social movements, online communities, and science communication. I have found that firstly, the two groups engage in two distinctive styles of communication with XR employing an academic, expertise-based use of hyperlinks and FFF emphasizing influencer-based content accessible to general audiences and emphasizing options to interact with local subgroups of the movement through a variety of digital channels. Secondly, both groups refer to a vast range of different resources, mixing different formats and sources of scientific information with a focus on natural sciences and an emphasis on establishing the extent and urgency of the issue. Finally, the two groups retain close ties to academic science and can act as science communicators in two ways: on the one hand by giving scientists a non-academic outlet to draw attention to their research (as indicated by statements of support and scientist-led subgroups of both movements and a close orientation to academic formats especially of XR), and on the other hand by acting as amplifiers of various channels of science communication.

The audiences of the websites and hence the potential reach of these efforts have not been subject of this study. Research indicates that climate science communication efforts risk "chanting to the choir" [Metcalfe, 2020]. Further research should examine whether the same applies to activist movements acting as alternative science communicators or whether they succeed in reaching alternative audiences, too. Future research on the use of science by activist movements should also consider the role of social media as another heterogeneous platform linking actors and content without clear demarcations of scientific and other sources and formats. The use of academic science side-by-side with other information and a variety of science communication channels employed by the two movements point to the importance of recognizing the diverse range of activities that science communication can encompass. How audiences of these sites view the presented content has not been part of this study but also deserves consideration. Finally, activism as an outlet for scientists to engage in science communication should receive more attention, for example by following the activities of organizations of scientists aligning themselves with climate movements such as Scientists for Extinction Rebellion, Scientists for Future, or Doctors for Extinction Rebellion.

Appendix A. Most frequently referenced sources

Most frequently referenced sources (domains linked to $\geq$ 10 times by either FFF or XR).

domain	FFF	XR UK	Description
mailto	107	88	E-mail addresses
facebook	80	100	Social media
twitter	157	19	Social media
instagram	108	6	Social media
nature	1	98	Academic journal
actionnetwork	2	80	Open online platform for organizing activism
rebellion		76	XR's own website
docs	3	62	Shared documents (Google docs)
youtube	21	30	Videos
ipcc		36	Intergovernmental Panel on Climate Change website
science		33	Academic journal
pnas		31	Academic journal
theguardian		31	News website
carbonbrief		30	Popular climate science
bbc		21	News website
agupubs		18	Academic journal (American Geophysical Union)
climate	1	17	Climate information by US government agencies (NOAA, NASA)
fridaysforfuture	16		FFF's own website
fao	2	13	Food and Agriculture Organization
sciencedirect	1	13	Academic Publisher (Elsevier)
advances		14	Academic Journal
forms		12	Google forms (used as contact forms)
iopscience		12	Academic Journal (Environmental Research Letters)
gov		12	UK-government websites
mckinsey		12	Consultancy
theconversation		11	Popular science/ news
un		11	United Nations websites
theccc		11	UK Committee on Climate Change
thelancet		10	Academic journal
skepticalscience		10	Climate Science Blog
Other hyperlinks	*68*	*542*	*Domain names referred to less than 10 times each*
Total	**567**	**1459**	

Appendix B. Media formats of linked sources from FFF and XR websites

media type summary	media type group	FFF	XR UK
	[other]	9	31
1 text dissemination	academic	5	322
	news	3	225
	Policy (e.g. reports)	6	180
	Crowdsourced (e.g. wiki, shared documents)	8	70
	popular science		44
2 multimedia dissemination	own website (i.e. FFF, XR, including local groups)	38	113
	external website	3	67
	Video	11	44
	social media content (e.g. posts, tweets)	35	4
	Visual	3	33
3 interactive media	social media groups and profiles	328	125
	contact point (e-mail, forms)	108	181
	call to action (e.g. campaigns, donation requests, volunteer or join requests)	9	11
	Feed (e.g. newsletter, RSS feed)	1	9
Total		**567**	**1459**

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