Journal of Environmental Psychology xxx (xxxx) 101596

Contents lists available at ScienceDirect

Journal of Environmental Psychology

journal homepage: www.elsevier.com/locate/jep

Global climate marches sharply raise attention to climate change: Analysis of climate search behavior in 46 countries

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ARTICLE INFO

Keywords:
Climate activism
Internet search analysis
Public attention to climate change

ABSTRACT

We examine attention to climate change in 46 countries across six continents from 2015 through 2019 by analyzing internet search activity in ten languages. We find that information seeking about climate change, measured by internet searches, notably increased in 2019 relative to prior years. Next, we analyze the impact of global climate marches on internet search activity and find that climate activist events are powerful drivers of attention compared to political events (United Nations Climate Change Conferences) and temperature abnormalities. To explore the role of media coverage, we estimate the effects of climate marches while controlling for weekly news coverage of climate change and find evidence supporting the notion of media attention mediating the effects of climate protests. Lastly, we quantify the duration of the increases in information seeking produced by these events. We find the durations are short-lived, with attention only staying above pre-event levels for several days. As the literature to date has paid scarce attention to public demonstrations as sources of influence on the public's attention to climate change, we suggest these results implore the field to focus more research on the impacts of climate activist events.

1. Introduction

In 2019, the world saw climate activism take place at an unprecedented magnitude. Though, there is scant published evidence that illuminates what effect, if any, this activism had on public attitudes on climate change. One exception is a monthly UK poll that showed dramatic increases in concern about the environment among UK citizens in 2019, occurring seemingly in conjunction with increases in climate activism events (Carrington, 2019). Since climate activism was rippling across the globe in 2019, this begs the questions of whether climate attitudes and attention changed notably worldwide and if climate activist events played a role.

In the current paper, we first investigate and quantify the extent to which information seeking about climate change increased in 2019. Next, we evaluate the effects of climate activism alongside other known drivers of climate attitudes, including temperature abnormalities and United Nations Climate Change Conferences[1] (Weber, 2010, 2016; ; Howe et al., 2019; Carmichael & Brulle, 2016; Fownes et al., 2018). We analyze information-seeking behaviors about climate change in the form of online searches. We hypothesize that climate activism has relatively strong effects on information seeking about climate change compared to other drivers.

This hypothesis relates to the Augmented Risk Information Seeking and Processing model developed by Kahlor (2007). This model augments the Risk Information Seeking and Processing (RISP) model by synthesizing it with Azjen's Theory of Planned behavior (TPB; Azjen 1991). Kahlor (2007) applies the Augmented RISP model explicitly to information seeking in the domain of climate change risk. This makes it most directly related to our hypothesis in contrast with the more general RISP or TPB frameworks it draws on.

The Augmented RISP model asserts that felt affects, risk perceptions, and perceived social norms about climate change, among other drivers, lead people to seek information about climate change. Climate activism can plausibly increase attention to climate change through

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[1] More formally known as the Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC).

https://doi.org/10.1016/j.jenvp.2021.101596
Received 12 August 2020; Received in revised form 16 March 2021; Accepted 26 March 2021
0272-4944/© 2021

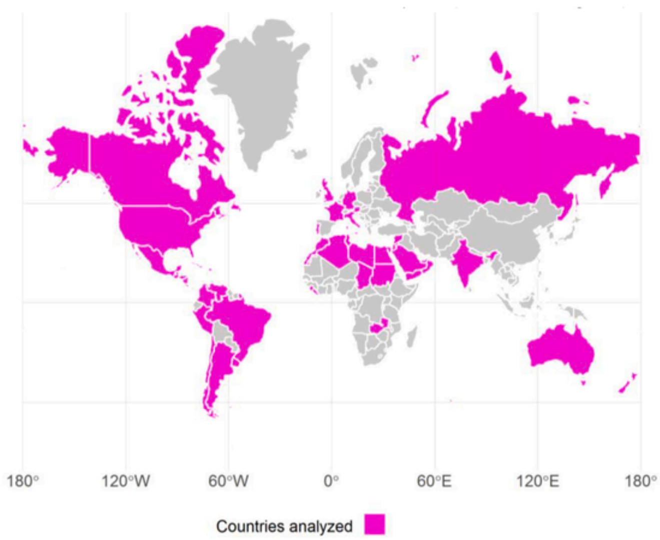

Fig. 1. World map showing countries analyzed (shaded in magenta).

Table 1
Countries analyzed.

Continent	Target countries
Africa	Algeria (DZ), Egypt (EG), Liberia (LR), Morocco (MA), Sudan (SD), Sierra Leone (SL), Tunisia (TN), Zambia (ZM)
Asia	United Arab Emirates (AE), Bahrain (BH), India (IN), Jordan (JO), Kuwait (KW), Lebanon (LB), Oman (OM), Saudi Arabia (SA), Syria (SY)
Europe	Austria (AT), Germany (DE), France (FR), United Kingdom (GB), Italy (IT), Portugal (PT), Russia (RU)
North America	Bermuda (BM), Canada (CA), Costa Rica (CR), Dominican Republic (DO), El Salvador (SV), Guatemala (GT), Honduras (HN), Jamaica (JM), Mexico (MX), Nicaragua (NI), Panama (PA), Trinidad and Tobago (TT), United States of America (US)
Australia/Oceania	Australia (AU), New Zealand (NZ)
South America	Argentina (AR), Brazil (BR), Chile (CL), Colombia (CO), Peru (PE), Uruguay (UY), Venezuela (VE)

each of these three mechanisms. This gives theoretical footing to our hypothesis that climate activism has strong impacts on information seeking. As people can feel moved when observing social activism (Landmann & Rohmann, 2020), activism can increase felt affect and lead individuals to learn more about climate change. Protests and other displays of activism also send an honest signal to the public that climate change is perceived by many as a serious risk, influencing risk perceptions. Witnessing (in person or through the media) crowds of people demonstrating about climate change may also increase perceptions of social pressure to pay attention to climate change.

To study information seeking about climate change, we analyze internet search activity (Choi & Varian, 2012). This methodology builds upon a variety of past research using online search activity to quantify information seeking behavior related to climate change. For example, Lang (2014) showed that local weather fluctuations impact climate searches, consistent with other research showing that weather experiences are associated with increased climate attention (e.g. Pianta & Sisco, 2020; Sisco et al., 2017). Kahn and Kotchen (2011) found a negative correlation between climate searches and searches on unemployment and replicated this effect using survey data paired with unemployment rates. Archibald and Butt (2018) estimated awareness about climate change using search volume data and showed a positive correlation between these estimates and the climate vulnerability of countries.

In the current paper, we first look at climate change search behavior trends from 2015 through 2019 in 46 countries. Second, we estimate the associations between climate marches and internet searches about climate change and compare them with the associations of major political events and temperature abnormalities with internet searches about climate change. Third, we examine the effects of climate marches while controlling for news coverage in a subset of our target countries (Gruszczynski & Wagner, 2017; King et al., 2017). Finally, we quantify the duration of the effects of climate marches on internet searches about climate change.

2. Material and methods

2.1. Translations

To quantify the intensity of Google searches about climate change in our target countries we translated "climate change" and "global warming" into English, French, Arabic, Spanish, Portuguese, German, Hindi, Russian, Italian, and Indonesian. The translations used for each language can be found in Supplementary Material 1.

2.2. Target countries

We selected countries whose top three official and top three most-spoken languages are all among the 10 languages we performed translations in. These strict criteria for country inclusion are to ensure we do not include a country with a significant portion of its population searching about climate change in a language we did not translate. Record of the official and most-spoken languages in each country were obtained from the GeoDist database (Mayer & Zignago, 2011). The countries we analyze in each continent are shown in Fig. 1 and Table 1. The countries included in our analyses cover about 41% of the global population.

2.3. Search intensity data

For each country, we extracted search frequencies for the variants of the expressions "climate change" and "global warming" in the country's main spoken languages. We also included the English language phrases for all countries as they are often used even in countries where English is not a primary language. The data we collected range from January 1st, 2015 through December 31st, 2019. The volume of searches about climate change in our data is a relative quantity: the proportion of all searches within a target area and timeframe. These proportions are then linearly rescaled so that the maximum value observed in a target area over the time range of the requested data equals 100. Since Google only allows queries of up to five keywords at a time, we developed an approach to harmonize results over multiple queries to accommodate countries with more than five keywords. More details on this harmonization procedure can be found in Supplementary Material 2.

Once we obtained the time series of search volumes for all keywords relevant to a given country and harmonized them, we summed them to result in a single time series of climate change search volume for each country. We transformed the search volume values into standard deviation units within the time series for each country for comparability. There is evident seasonality in the patterns of climate search activity, which can be seen in Supplementary Material 3. Thus, we modelled out the seasonal effects prior to analysis or included seasonal fixed effects in all analyses.[2]

[2] We deseasonalized weekly data by fitting a regression model with search activity regressed on seasons represented as dummy variables and used the residuals from this regression model as our focal values in visualizations/analyses (except analyses that control for seasonality).

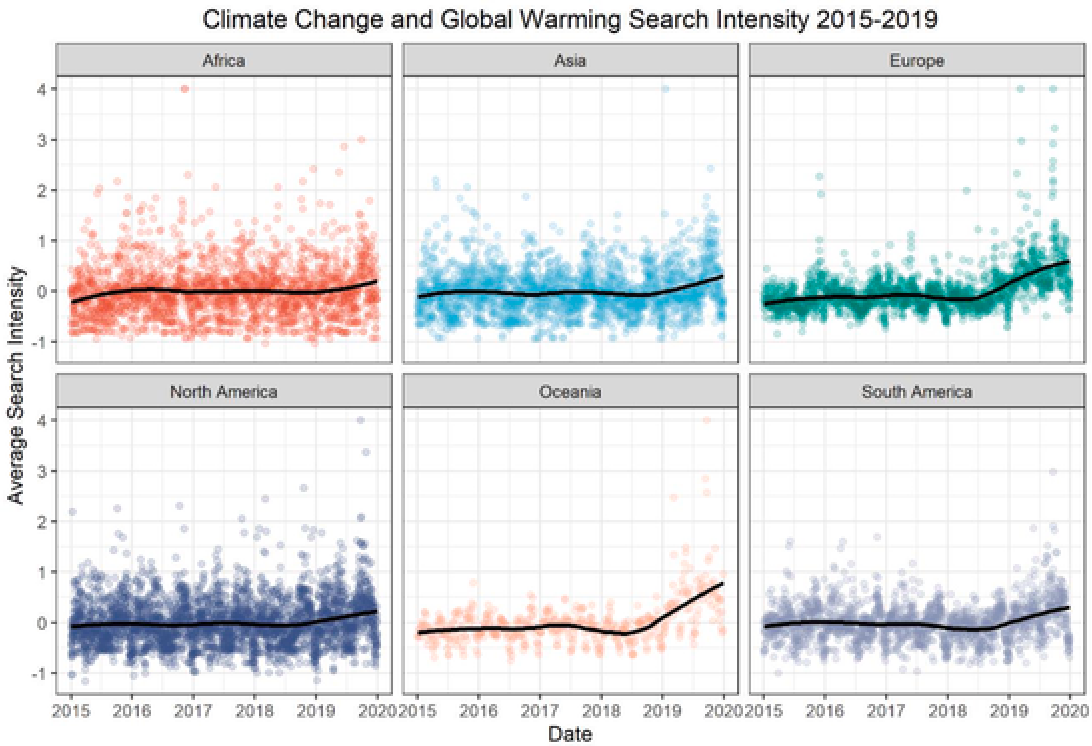

Fig. 2. Climate Change search intensity (deseasonalized) from 2015 to 2019 across six continents.[3].

2.4. Temperature data

We calculated weekly temperature abnormalities for each country using temperature data from the National Oceanic and Atmospheric Administration's (NOAA) Global Historical Climatology Network (GHCN) weather database. To quantify temperature abnormality, we calculated the difference between daily maximum temperature values (averaged for each country) and the historical average for the same day and country from the past 15 years. To analyze a week-level value, we take the maximum daily deviation value for each week and country. More details on our temperature calculations can be found in Supplementary Material 4.

3. Results

3.1. Trends in climate change information seeking from 2015 to 2019

First, we examine trends in climate change information seeking from 2015 through 2019 across the world. Fig. 2 presents the loess smoothed time series and the deseasonalized underlying data for the six continents our target countries reside in.

A notable global increase in attention to climate change in 2019 is visually and statistically evident[4]. We regressed deseasonalized search intensity on a dummy variable indicating if each observation is from the year 2019 or prior, while accounting for nestedness within countries using clustered standard errors (Arellano, 1987). We found a global positive increase in attention in 2019 compared to past years ($b = 0.26$; 95%CI $= [0.19, 0.32]$; SE $= 0.035$; $p<0.001$). The full regression table is shown in Supplementary Material 5.

[3] Outliers above four standard deviation units were excluded from this visualization.

[4] The code used to implement all of our analyses is shared in Supplementary Material 10.

Table 2
Weekly search volume predicted by UNCCC events, Local temperature abnormalities, and climate protests.

	Dependent variable:
	DV: Search Volume
Climate Protest	0.27***
	(0.05)
Temp. Abnormality	0.01**
	(0.003)
CC Conference – Katowice (2018)	0.01
	(0.03)
CC Conference – Bonn (2017)	0.22***
	(0.04)
CC Conference – Marrakech (2016)	0.42***
	(0.10)
CC Conference – Paris (2015)	0.44***
	(0.06)
Week	0.001***
	(0.0002)
Constant	−2.29***
	(0.49)
Observations	9366
Country fixed effects	✓
Seasonal fixed effects	✓
Adjusted R^2	0.1

Note: SEs are clustered within country. Search volume is in within country standard deviation units.
*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

3.2. Estimating the effects of climate marches on search volume

To address the question of what determined the increase in search volume in 2019, we conduct a regression analysis to estimate the associations between the two largest climate protests, held on March 15th and September 20–27th 2019, and information seeking about climate change. For comparison, we also estimate the effects of United Nations Climate Change Conferences and local temperature abnormalities, which have both been shown to drive public attention to climate change. To implement this, we regress weekly country-level search volume (in within country standard deviation units) on a binary variable indicating if a climate protest occurred that week, binary indicators for specific UN Climate Change Conferences occurring, a continuous measure of (maximum) weekly temperature abnormality, a continuous time variable, season dummy variables, and country fixed effects. We clustered standard errors within country. The results are shown in Table 2. In this regression analysis, the countries Bermuda, Guatemala, Liberia, Panama, and Sierra Leone are not included as we could not retrieve sufficient temperature data for these areas.[5]

In support of our main hypothesis, we find that the effects of climate marches on information seeking about climate change are sizable in comparison with other key drivers. The average effect of the two largest climate marches in 2019 is 61% of the increase produced by the landmark UN Climate Change Conference that produced the Paris agreement. In comparison to the effects of temperature abnormalities, we estimate the effect of these climate marches to be about 27 times the effect of a 1-degree Celsius (weekly maximum) temperature abnormality.

3.3. Examining the role of media coverage

The strong effects of climate activism we report above prompt the question of what the role of news media coverage is. To address this question, we combined our search volume data with records of weekly online news coverage of climate change for six of the 46 countries – those that we could retrieve news media data for using the dataset created by Pianta & Sisco, 2020. We normalized media coverage to be in standard deviation units within country. A visualization of weekly media coverage overlapped with weekly search volume on climate change is shown in Fig. 3. We first fit a regression model to estimate the effect of climate marches in these six countries (see Model 1 in Table 3) and then add a variable representing the country-level media coverage of climate change each week and a variable representing a one-week lag of media coverage (see Model 2 in Table 3).

In these results, we can see that news media have a strong association with searches about climate change. The R^2 values increase from 18% to 35% variance explained when we add the news coverage variables. Our estimated effect of climate marches decreases by 40% when we add the news coverage variables to the model, suggesting that part of the effect of climate protests on information seeking behavior is due to increased news attention. The estimated effect of climate marches on search behavior is no longer statistically significant this model, but remains relatively large in magnitude while controlling for the effects of news coverage. Based on these results we cannot conclude whether or not climate marches have significant effects on societal attention to climate change beyond those caused by the increase in news coverage they generate.

3.4. Examining attention to climate change in 2019

We next turn to examine the climate change search intensity in the year 2019 more closely. Fig. 4 shows the weekly search intensity for climate change in our target countries over the year 2019. It is visually apparent that the largest and most coordinated peaks across countries were on the days of the global climate strikes: March 15th, 2019 and September 20th-27th, 2019. In March 2019, the strikes were held on one day and in September 2019 they were held over a week. In Supplementary Material 6, for comparison, we show search patterns over time for the main organizer of the climate strikes, Greta Thunberg.

[5] Post-hoc power analysis for all main analyses can be found in Supplementary Material 9.

3.5. Quantifying the decay rate of increased attention

Given that the global climate marches of 2019 appear to be important focal points of attention to climate change, we next zoom in to examine the climate change search activity in the weeks immediately before and after these events. We seek to explore the dynamics and duration of the events' effects.

We look first at the effects of the March 2019 event. We look at the subset of nine countries (Argentina, Austria, Australia, Egypt, Germany, France, New Zealand, Portugal, and Trinidad and Tobago) where the highest within-country search intensity in the time between February and May 2019 was around the time of the March 15th climate strike event, suggesting the events had a notable impact on the citizens of these countries. In the top panel of Fig. 5, we show the daily values of climate search intensity for these countries in thin colored lines and the average search intensity in a thick black line. The horizontal dotted line shows the baseline average search intensity prior to the event. This baseline is the average search intensity from Feb 1st, 2019 up to one week directly prior to the event. We see that information seeking about climate change built up a few days before the protests and fairly quickly returned to the pre-event baseline level afterwards.

We also examine the effects of the September 2019 climate events. In this analysis, we focus on the subset of 25 countries where the highest search intensity in the timeframe surrounding the strike (between mid-August and November 2019) was during the September 20th-27th climate strike events. In the bottom panel of Fig. 5 we show the daily values of climate search intensity for these countries (in the thin colored lines), the average search intensity (in a thick black line), and the baseline average search intensity (in the horizontal dotted line). The baseline value is the average search intensity from August 15th up to one week directly prior to the first event. In the September 2019 climate strikes, events were held from September 20th-27th so we use the 27th, the final day of the events, to calculate the duration of the effects on attention. Again, we can see that it takes only a few days before the increased attention to climate change returns to the level of the pre-event baseline.

To statistically quantify the effects' durations, we analyze how long increased search intensity stayed statistically higher than baseline levels for each event. We first modelled out the effects of weekends and weekdays on the daily search intensity values. We fit regression models predicting climate search volume with dummy variables representing discrete numbers of days following each event.

We present these results in Table 4. The constant terms (y-intercepts) serve as baselines which include all daily observations from six weeks before each event and up to one week prior. We see that by five days after the March 15th event there is no significant difference in the climate search intensity compared to baseline levels. We also show that by seven days after the September 20–27th event there is no significant difference in the climate search intensity compared to baseline levels.

The results do not necessarily indicate that the effects of the events are completely removed after four to seven days, rather that the largest share of the effects have dissipated. For example, on the ninth day after the September 20–27th event there was a modest but significant increase in climate searches that may or may not have been due to the recent climate march event.

For a point of comparison, in Supplementary Material 7 we report results from a similar analysis where we quantify the duration of increased attention to climate change caused by the 2015 Paris UN Climate Change Conference. We find that the decay of increased search volume from this historical conference decreased even faster than the effects of the 2019 climate marches. Similarly, in Supplementary Material, 8 we show the daily-level search volume about Greta Thunberg (the main organizer behind the 2019 climate events) before and after the September protest.

Fig. 3. Weekly (deseasonalized) internet search intensity is shown by the thin lines and weekly online news coverage of climate change is shown by the thick lines.

Table 3
Examining the role of news coverage.

	DV: Climate Change Search Volume	
	(M1)	(M2)
Climate news		.39*** (0.62)
Climate news (lag)		.14*** (0.35)
Climate march	0.30* (0.13)	0.18 (0.11)
Week	0.003*** (0.0003)	0.001*** (0.0004)
Constant	−5.21*** (0.82)	−2.25** (0.85)
Observations	1512	1506
Country fixed effects	✓	✓
Seasonal fixed effects	✓	✓
Adjusted R^2	0.18	0.35

Note: SEs are clustered within country.
*P < 0.05; **P < 0.01; ***P < 0.001.

4. Discussion

In the current paper, we examine information seeking behavior about climate change in 46 countries across six continents from 2015 through 2019. Analyzing the volume of internet searches for the expressions "climate change" and "global warming" shows that information seeking increased in 2019.

We then analyze the association between climate protests and internet search behavior, and find that such events are associated with sizable increases in internet searches about climate change, comparable to increases produced by international political events and temperature abnormalities. These findings suggest that we should include public demonstrations in the set of key drivers we focus on in research and policy design. While little past research has focused directly on the impact of public demonstrations about climate change, some work has indirectly anticipated their potential, including findings on the sizable effects of perceptions of social norms (e.g. Osbaldiston et al., 2012), which may shift in response to public demonstrations. Some studies have shown significant effects of public demonstrations on public attention to other issues such as war protests (McAdam & Su, 2002), immigration rights (Wallace et al., 2014), and political movements (Madestam et al., 2013). Other studies have looked at the motivations of activists for participating in public demonstrations (Roser-Renouf et al., 2014; Feldman & Hart, 2016; Wahlström et al., 2019).

After analyzing the effects of the climate marches on public information seeking about climate change, we quantified their durations. We find that the increases in attention above pre-event levels are short-lived, lasting only four to seven days. This finding has implications for research on public demonstrations (Swim et al., 2019). Future research on the effects of climate activist events should ensure their baseline measurements are made with sufficient lead time before the start of the events (to avoid capturing pre-event effects in baseline measures). In addition, post-event measurements should begin immediately after the events conclude (to avoid underestimating effects that fade quickly).

One limitation of our findings is that we cannot ascertain what demographic groups are responsible for the increases in information seeking about climate change that we observe. We cannot rule out that it is primarily citizens who are already concerned about climate change who increase their information-seeking response to climate activist events.

We cannot necessarily infer from our results that climate protests are the sole or primary cause of the increased attention to climate change we observe in 2019. In the past, global climate marches leading

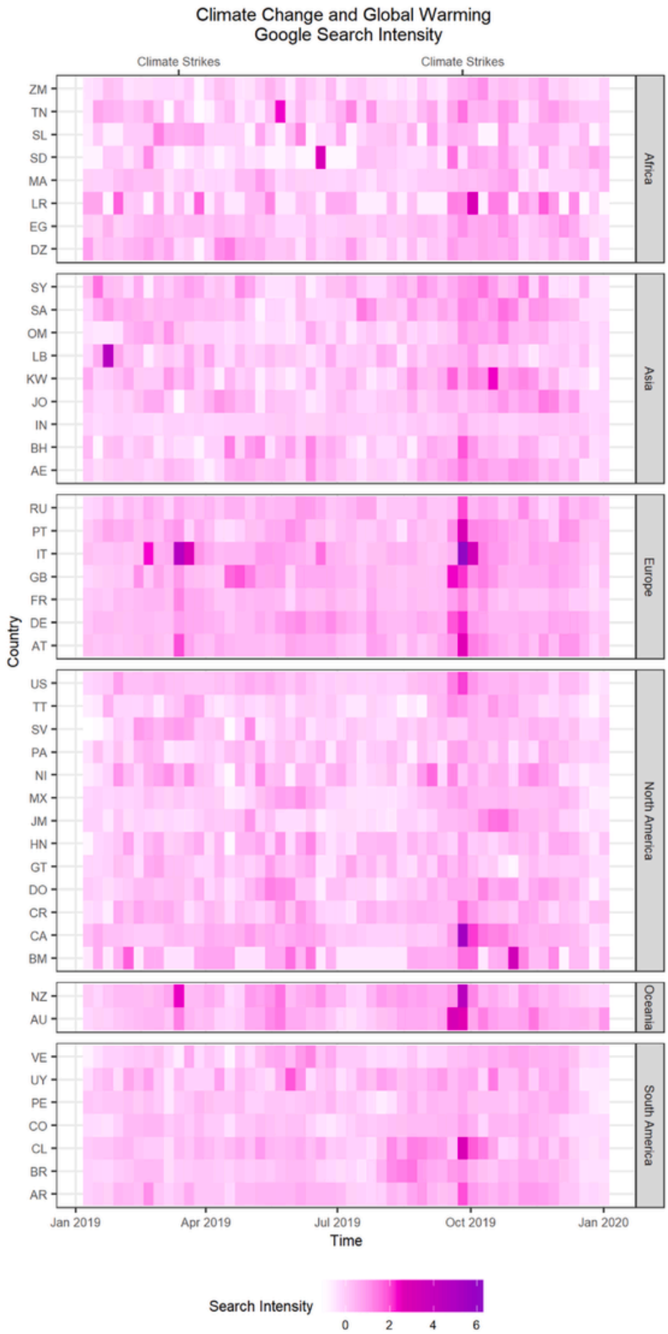

Fig. 4. Weekly deseasonalized search intensity for climate change during 2019 in 46 target countries.

up to the 2015 Paris Climate Summit took place in more than 175 countries without generating the same momentum as seen around the 2019 climate events. This could be because past events were not accompanied by a simultaneous increase in societal concern about climate change generated by other forces, such as increasing extreme weather events and increasing dissemination of knowledge about climate change (Cheng, 2020; Xu, Wang, Liu, Chen, & Huang, 2020).

Putting aside the question of how much responsibility for international increased attention to climate change we can attribute to the global climate marches, we provide evidence that international surges in attention to the issue are sparked by them and concentrated around them. This suggests that the community of climate change scholars, policy-makers, advocates, and activists should recognize such global activism events as uniquely capable of increasing, at least for short periods, attention to this issue. Climate change is now widely recognized as a fundamentally global problem (World Economic Forum, 2020; Ballew et al., 2019; Lee et al., 2015), and relevant policy solutions require global action (Somanathan et al., 2014; Sterner et al., 2019). Global activism may help open windows of opportunity to put in place the policies needed to reach ambitious global decarbonization targets (Kingdon & Stano, 1984).

Declaration of competing interest

None.

Acknowledgements

This research was funded by 1.) the European Research Council under the European Community's Programme “Ideas” — Call identifier: ERC-2013-StG/ERC grant agreement no. 336703—project RISICO “Risk and uncertainty in developing and implementing climate change policies”, 2.) the National Science Foundation through the award NSF-1144854 “IGERT: From Data to Solutions: A New PhD Program in Transformational Data & Information Sciences Research and Innovation”, 3.) the cooperative agreement NSF SES-1463122 awarded to the Center for Research on Environmental Decisions and 4.) generous support from Alice Bordini Staden.

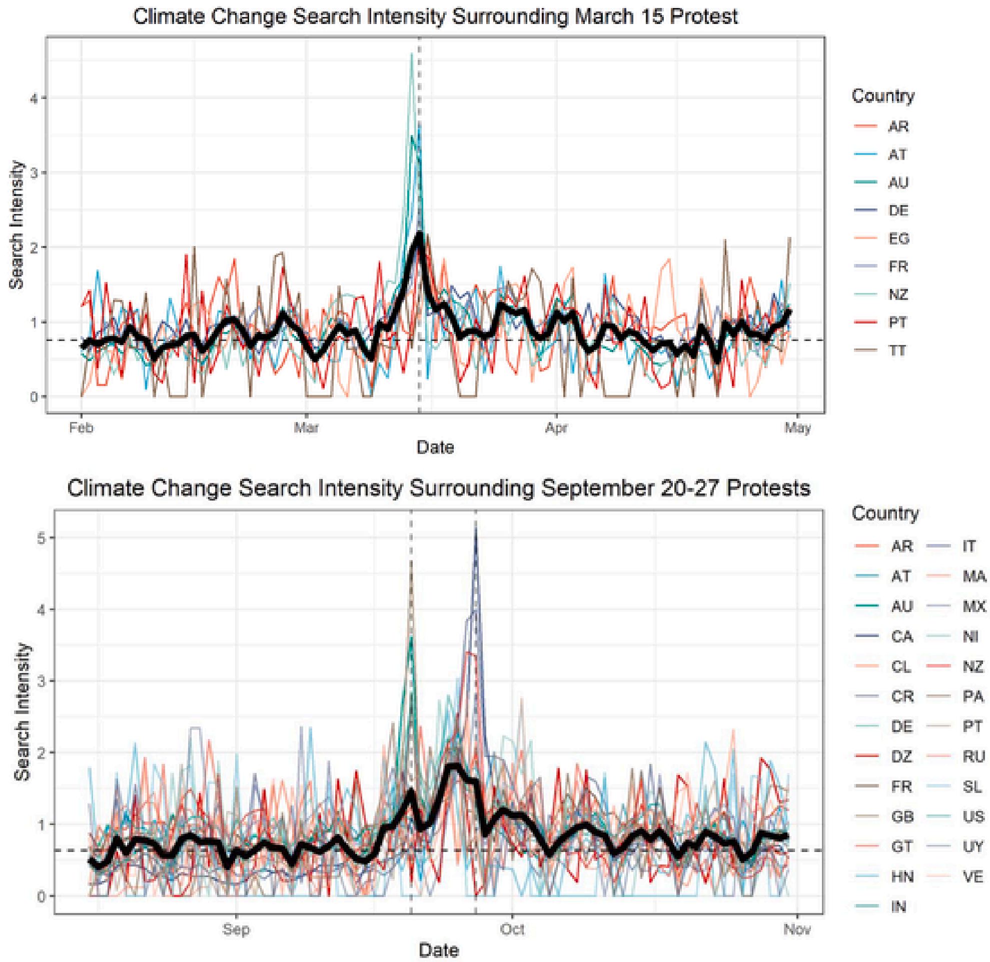

Fig. 5. Top panel: climate change search intensity surrounding the March 2019 global climate strike. Bottom panel: climate change search intensity surrounding the September 2019 global climate strikes.

Table 4
Climate search intensity regressed on number of days since event.

	Event: March 15th DV: Search Intensity	Event: September 27th DV: Search Intensity
	M1	M2
Day of event	1.35***	.87***
	(.27)	(.24)
1 day after	.72***	.38**
	(.20)	(.13)
2 days after	.48***	.60***
	(.09)	(.13)
3 days after	.41**	.47***
	(.13)	(.11)
4 days after	.24**	.39***
	(.09)	(.08)
5 days after	-.04	.39**
	(.15)	(.13)
6 days after	.04	.27**
	(.15)	(.10)
7 days after	.04	.07
	(.14)	(.09)
8 days after	.13	.10
	(.11)	(.06)
9 days after	.16	.27**
	(.10)	(.09)
Constant	-.09***	-.17***
	(.01)	(.02)
Observations	405	950
Adjusted R^2	.25	.13

Notes: SEs are clustered within country. Weekend/weekday effects were modelled our prior to analysis.
*P < 0.05; **P < 0.01; ***P < 0.001.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvp.2021.101596.

Author statement

Matthew R. Sisco: methodology, formal analysis, data curation, writing – original draft. Silvia Pianta: conceptualization, writing – review & editing. Valentina Bosetti: conceptualization, writing – review & editing, supervision. Elke U. Weber: conceptualization, writing – review & editing, supervision.

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