environments

Article

From Global Health to Global Warming: Tracing Climate Change Interest during the First Two Years of COVID-19 Using Google Trends Data from the United States

Lena Hoffmann [1], Keno K. Bressem [1,2], Jonas Cittadino [1], Christopher Rueger [1], Phillip Suwalski [3], Jakob Meinel [4,5], Simon Funken [6] and Felix Busch [1,*]

[1] Department of Radiology, Charité—Universitätsmedizin Berlin, Corporate Member of Freie Universität Berlin and Humboldt Universität zu Berlin, 10117 Berlin, Germany; lena.hoffmann@charite.de (L.H.); keno-kyrill.bressem@charite.de (K.K.B.); jonas.cittadino@charite.de (J.C.); christopher.rueger@charite.de (C.R.)
[2] Berlin Institute of Health at Charité—Universitätsmedizin Berlin, 10178 Berlin, Germany
[3] Department of Cardiology, Charité—Universitätsmedizin Berlin, Corporate Member of Freie Universität Berlin and Humboldt Universität zu Berlin, 12203 Berlin, Germany; phillip.suwalski@charite.de
[4] Clinic of Pediatric and Adolescent Medicine, University of Luebeck, 23562 Luebeck, Germany; jakob.meinel@uksh.de
[5] German Alliance for Climate Change and Health (KLUG), 10997 Berlin, Germany
[6] Schumpeter School of Business and Economics, University of Wuppertal, 42119 Wuppertal, Germany; funken@wiwi.uni-wuppertal.de
* Correspondence: felix.busch@charite.de

Abstract: Climate change mitigation depends on actions that affect the public interest and lead to widespread changes in public attitudes and behavior. With the global outbreak of the COVID-19 pandemic, humanity faced a more imminent threat to its well-being and viability. This retrospective cross-sectional study examines how public interest in climate change was attenuated by the severity of the COVID-19 pandemic using Google Trends Search Volume Index (SVI), weather, and climate data on a United States state-level basis during the first two years of the pandemic from 2020 to 2022. To identify channels through which the COVID-19 pandemic affected information demand on climate change, a novel fixed effect regression model of public climate change interest was developed. The measure captures changes in the climate change SVI independent of weather and climate conditions, comprising pandemic-related changes in living circumstances such as COVID-19-related cases and deaths, mask mandates, and the proportion of the vaccinated population. Our results indicate that public interest in climate change was systematically attenuated by the severity of the COVID-19 pandemic. In addition, this study provides an approach for identifying drivers of public interest in climate change.

Keywords: climate change; COVID-19 pandemic; Google Trends; public interest; United States

check for updates

Citation: Hoffmann, L.; Bressem, K.K.; Cittadino, J.; Rueger, C.; Suwalski, P.; Meinel, J.; Funken, S.; Busch, F. From Global Health to Global Warming: Tracing Climate Change Interest during the First Two Years of COVID-19 Using Google Trends Data from the United States. *Environments* **2023**, *10*, 221. https://doi.org/10.3390/environments10120221

Academic Editors: Hai-Ying Liu and Daniel Dunea

Received: 18 November 2023
Revised: 8 December 2023
Accepted: 11 December 2023
Published: 13 December 2023

1. Introduction

Human-induced climate change is one of the most critical issues facing global society and health. The recently published Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) highlights a range of mechanisms that have been shown to affect global physical and mental health negatively and can be attributed to human-induced climate change, such as increased heat events causing mortality and morbidity, the rise of food- and water-borne diseases, expanded vector-borne diseases, emerging zoonoses, and exacerbated health issues related to water quality, temperature, and extreme weather events [1]. To shape public attitudes toward greater awareness of human-driven climate change, initiatives, and political measures may promote changes in individual and social behaviors [2]. Possible interventions include the introduction of political regulations, economic development strategies, and education about climate change, its impact, and

prevention [3–5]. Identifying channels that potentially oppose the success of such initiatives has important implications for promoting climate change mitigation and adaptation more effectively. One example is the organization of global climate strikes via social media by movements such as 'Fridays for Future,' positively shaping the public interest and leading to a new stream of climate change activism [6–8]. However, the outbreak of the COVID-19 pandemic had an immediate impact on such initiatives as measures to contain the pandemic affected their feasibility.

The experiences and lessons learned from the COVID-19 pandemic have illuminated the possibility of rapid, decisive action in addressing global challenges, including that immediate, tangible consequences and the perceived effectiveness of individual and collective actions significantly amplify public responses [9,10]. In contrast, the less immediate and more complex effects of climate change are less tangible to the public, which complicates the linking of individual behavior and environmental outcomes. Therefore, understanding public interest and behavior related to climate change may foster the development of effective policies and actions that are consistent with frameworks that promote climate resilience and adaptation, including regional networks, decision support tools, regional solutions, resilience pathways, and knowledge-sharing to intervene in key community systems such as health, primary production, water, environment, and infrastructure [11].

Although public adaptation to COVID-19 containment has shown that environmental conditions can change rapidly through human behavior, leading, for example, to significant reductions in short-term nitrogen dioxide levels, public expectations regarding the impact of COVID-19 on climate change mitigation were mixed [12–15]. In a 2022 survey of 2200 people in Spain by Savin et al., a predominantly pessimistic outlook toward climate action was reported, with concerns surrounding limited financial resources due to the focus on healthcare and economic recovery [16]. In addition, results from a 2022 survey of the International Monetary Fund with 14,500 respondents from 16 major economies indicated growing support for green recovery initiatives post-pandemic, along with increasing public concern about climate change. Particularly, 43% of global respondents reported a higher concern about climate change since the outbreak of the pandemic, suggesting a growing awareness of the interconnectedness of global health and environmental issues [17]. These changes in public awareness indicate that global health events such as the COVID-19 pandemic also provide opportunities for the implementation of bolder climate policies, and thus, the analysis of public interest alterations is a critical factor in advocating for future climate action and policy development [18].

To determine how the COVID-19 pandemic influences public interest in climate change, with its severe impact on global well-being and the economy, analyzing big data from internet search engines such as Google can be beneficial. Internet search activities have been shown to be strongly linked to people's current interests, which is a critical requisite for forming political majorities that may steer legislation and changes in personal behavior [19–21]. Furthermore, the information provided and processed by search engines has a massive influence on human behavior and decision-making [22,23]. Based on current public perceptions, environmental scientists may respond and modify their strategies to enhance climate change mitigation activities and successful adaptation [24–26].

Google Trends allows the public to examine Google searches and trends based on the Search Volume Index (SVI). The SVI is a representation of the relative popularity of a given search term or topic. SVI values are normalized to a scale from 0 to 100, where 100 is defined as the maximum proportion of all searches in the selected period and geographic region [27]. Queries related to topics can capture a variety of search terms that share a common concept across different languages, spellings, and acronyms. Since the Google search engine accounts for over 90% of global internet searches, the SVI is a powerful tool to identify and predict temporal trends in information demand for various disciplines, including public health, business, communications, and economics [28–31].

With the global outbreak of the COVID-19 pandemic, humanity faced a more immediate threat to well-being and viability other than climate change, with living circumstances

severely impacted by measures containing the pandemic. This study hypothesized that the severity of the pandemic directly affected the broad public recognition of threats and risks associated with climate change, and consecutively, people tended to be less interested in climate change the more the pandemic impacted their lives. As climate change mitigation strongly depends on actions that affect the public interest and lead to widespread changes in public attitudes and behavior, it is relevant to examine how exceptional situations such as the pandemic have shaped these factors and what lessons can be learned for the future. Therefore, this study uses Google Trends data from 2020 to 2022 to examine how public search interest in climate change evolved during the first two years of the COVID-19 pandemic in the United States (US).

2. Materials and Methods

Because this retrospective cross-sectional study was based on publicly available data, institutional review board approval was not required following our institution's policies.

2.1. COVID-19 Data

For longer periods, SVI values are as granular as weekly. Therefore, empirical COVID-19 data for this study were analyzed from 26 January 2020 to 30 January 2022, as the first official COVID-19 case in the US was documented on 21 January 2020. Daily US state-level COVID-19 data, such as incidence, mortality, weekly county-level data on mask mandates, and the weekly rate of state inhabitants vaccinated against COVID-19 at least once, were retrieved from the US Centers for Disease Control and Prevention (CDC; accessed on 15 January 2023 at: https://www.cdc.gov). Daily data were summarized as a weekly mean for comparison with the corresponding SVI values.

2.2. Google Trends Data

Google Trends data analyzed in this study included weekly SVI values of the topics 'climate change' and 'coronavirus disease 2019 [disease]', both predefined by Google Trends, for 48 US states between 26 January 2020 and 30 January 2022 to investigate channels through which the search interest in climate change may be affected by the severity of the COVID-19 pandemic within the first two years of the pandemic. The states of Alaska and Hawaii were excluded from analyses, as certain control variables (e.g., Climate Extremes Index (CEI), Palmer Z Index) were not available for one or both states. Google Trends data were retrieved from https://trends.google.com/trends on 16 January 2023.

2.3. Weather Data

Monthly data on state-level temperature anomalies, precipitation, and drought severity (Palmer Z Index) were retrieved from the US National Center of Environmental Information (NCEI; accessed on 16 January 2023 at https://www.ncei.noaa.gov). Furthermore, the US CEI was analyzed (accessed on 16 January 2023 at: https://www.ncdc.noaa.gov/extremes/cei), a three-month aggregate that captures the extent to which climate extremes (e.g., streaks of extreme weather and tornados) impacted the landmass of nine US regions following Karl and Koss [32]. Additionally, the US state-level data on the area burned by wildfires was taken into account, provided by the National Interagency Fire Center in its annual report (NIFC; accessed on 16 January 2023 at: https://www.nifc.gov).

Please refer to Table 1 for an overview of all main variables used for analysis, including the definition and data sources.

Table 1. Overview of main variables, their definition, and data sources used for analyses in this study.

Variable	Definition	Source
climate change	SVI of the topic 'climate change' for each US state	Google Trends
coronavirus 2019 disease	SVI of the topic 'coronavirus 2019 disease [disease]' for each US state	Google Trends
cases	Weekly new COVID-19 cases per 100,000 state inhabitants	CDC, Census 2020
deaths	Weekly new COVID-19 deaths per 100,000 state inhabitants	CDC, Census 2020
mask mandates	US population affected by mask mandates (based on population per county)	CDC, Census 2020
skeptical/leaders	Takes a value of 1 if the weekly ratio of vaccinated people with at least one dose of vaccination within the US state is lower/higher than the interstate median	CDC
temperature anomaly	Average monthly temperature deviation in the US state from the 100-year period 1910–2010	NCEI
rain	Monthly precipitation for the US state	NCEI
Palmer Z	Index measures short-term drought on a monthly scale for the US state	NCEI
CEI	US Climate Extremes Index, 3-month aggregate, regionally grouped	NCEI
wildfire	Takes a value of 1 if the US state is among the top quantile of area burned by wildfires within the respective year	NIFC

CDC, Centers for Disease Control and Prevention; CEI, Climate Extremes Index; NCEI, National Center of Environmental Information; NIFC, National Interagency Fire Center; SVI, Search Volume Index.

2.4. Statistical Analysis

RStudio (RStudio, Boston, MA, USA) with the 'plm' package was used to examine panel data on weekly US state-level observations.

Lang showed that search interest in climate change is driven by several factors related to climate extremes and weather conditions [26]. Following the idea that current weather conditions drive the demand for additional knowledge and information on climate change, a fixed effect regression model was developed on the SVI of the topic climate change for state i in week t:

$$\text{SVI climate change}_{i,t} = \alpha_i + \beta_{1,i} * \text{temperature anomalies}_{i,\text{month}} + \beta_{2,i} * \text{rain}_{i,\text{month}} + \beta_{3,i} * \text{Palmer Z}_{i,\text{month}} + \beta_{4,i} * \text{CEI}_{\text{region,quarter}} + \beta_{5,i} * \text{wildfire}_{i,\text{year}} + \text{FE} + \varepsilon_{i,t}$$

Temperature anomalies refer to the deviation from the 100-year mean temperature (1910–2010) in state i in the month corresponding to week t. Rain is based on the monthly mean amount of precipitation observed in state i in the month corresponding to week t. The Palmer Z Index measures the severity of statewide drought. Negative values indicate the prevalence of drought periods in state i during the month corresponding to week t. The US CEI measures to what extent the region of US state i is affected by weather extremes in the corresponding quarter. Wildfire is a binary variable, which takes a value of one if state i is among the top quantile of US states affected by wildfires during the year corresponding to week t. Calendar week, region, and state-level fixed effects capture the extent to which unobserved heterogeneity among different states and regions affects the association between the model parameters.

To identify channels through which the COVID-19 pandemic affects information demand on climate change, the residuals of the aforementioned regression model were used (i.e., the SVI of climate change on current weather conditions was orthogonalized) to identify the public climate change interest independent of extreme weather fluctuations (weather-independent climate change interest). Weather-independent climate change interest captures changes in SVI that do not result from the current weather conditions the population of certain regions and states is exposed to. It can be assumed that much of this weather-independent climate change interest is directly affected by the population's general

awareness of the threats and risks associated with climate change. This study hypothesized that the severity of the COVID-19 pandemic during the years 2020 to 2022 directly affected the people's recognition of threats and risks associated with climate change. Thus, people might be less interested in climate change the more the pandemic impacts their lives. Based on this hypothesis, the following fixed effect regression model on the measure of weather-independent climate change interest for state i in week t was developed:

$$\text{Weather-independent climate change interest}_{i,t} = \alpha_i + \beta_{1,i} * \text{cases}_{i,t} + \beta_{2,i} * \text{deaths}_{i,t} + \beta_{3,i} * \text{mask mandates}_{i,t} + \beta_{4,i} * \text{leaders}_{i,t} + \text{FE} + \varepsilon_{i,t}$$

Cases and deaths refer to the sum of new cases and total deaths per 100,000 inhabitants of state i in week t. Mask mandates measure the fraction of the population of the state i that is potentially affected by county-level mask mandates in week t. Leaders is a binary variable that takes a value of one if the fraction of a state's population vaccinated at least once is higher than the interstate median during week t. Calendar week, region, and state-level fixed effects capture the extent to which unobserved heterogeneity among different states and regions affects the association between the model parameters, i.e., by comparing one model without and one model that includes regional- or state-level fixed effects (depending on the granularity of data) for each outcome variable.

3. Results

Table 2 displays the results of the fixed effect regression analysis for the weekly US state-level panel from 26 January 2020 to 30 January 2022.

Specifications (1) and (2) regressed various variables capturing current weather conditions on the SVI for the topic of climate change. The model parameters indicate that directly observable weather conditions significantly affected public interest in climate change. Temperature anomalies were associated with a higher SVI (+0.4086), indicating that interest in climate change is more significant when temperatures are perceived to be higher than expected. Further, a negative association of precipitation (−0.5778) and Palmer Z Indices (−0.2577) with the SVI on climate change was identified. Controlling for region-level fixed effects resulted in non-significant parameters for temperature anomalies and drought severity (Palmer Z). In contrast, the negative effect of rain was persistently strong. CEI and wildfires showed significant associations with the SVI on climate change. However, the relationships changed to the contrary when controlling for region-level fixed effects.

Models (3) and (4) show the results for specifications regressing different measures of the severity of the COVID-19 pandemic on the SVI of the topic coronavirus disease 2019. As variables were incorporated based on the fraction of state inhabitants that received at least one dose of vaccination, the observations within the panel focused on the period between December 2020 and January 2022 (as vaccination in the US only became available at the end of 2020). The association between the COVID-19 incidence and the SVI was extensively small (0.0088). Nevertheless, when controlling for unobserved heterogeneity among different states (specification 4), a slightly positive effect of weekly cases on the SVI (0.0093) and a negative effect of deaths related to COVID-19 (−0.0077) infections could be identified. Mask mandates showed a strong positive association with the SVI (1.7721). Controlling for unobserved heterogeneity among the states allowed for analyzing the effect of differences that seem to affect this association significantly. A positive effect of the fraction of vaccinated people (skeptical) below the interstate median and search volume on coronavirus was identified (0.6161).

Table 2. Results of fixed effect regression analysis for the Search Volume Indices of the topics climate change, coronavirus disease 2019, and the weather-independent climate change interest for the US states from January 2020 to January 2022.

Variable	SVI Climate Change		SVI Coronavirus Disease 2019		Weather-Independent Climate Change Interest	
	(1)	(2)	(3)	(4)	(5)	(6)
temperature anomaly	0.4086 ** t = 5.4019	0.0810 t = 1.1697				
rain	−0.5778 ** t = −4.3447	−0.7863 ** t = −5.3712				
Palmer Z	−0.2577 * t = −1.7257	0.0513 t = 0.3621				
CEI	0.1178 ** t = 7.9165	−0.0266 * t = −1.8255				
wildfire	−1.7235 ** t = −3.8402	1.1023 * t = 1.8295				
cases			0.0088 ** t = 30.1441	0.0093 ** t = 37.5233	0.0015 t = 1.2291	0.0011 t = 0.9414
deaths			−0.0067 ** t = −9.9645	−0.0077 ** t = −3.5281	−0.0177 ** t = −6.2795	−0.0207 ** t = −6.9992
mask mandates			1.7721 ** t = 13.0809	1.3484 ** t = 8.7425	−0.7705 t = −1.3574	0.2883 t = 0.4631
skeptical			−1.5232 ** t = −14.5931	0.6161 ** t = 4.4377		
leaders					5.8801 ** t = 13.4449	3.3580 ** t = 6.6345
Calendar week FE	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	No	Yes	No	No	No	Yes
State FE	No	No	No	Yes	No	No
R^2	0.0397	0.2254	0.3523	0.5877	0.0854	0.1522
Adjusted R^2	0.0186	0.2072	0.3378	0.5715	0.0650	0.1309

Temperature anomaly indicates the deviation of the monthly statewide mean temperature from the period of 1910–2010. Rain indicates the monthly statewide mean level of precipitation. Palmer's Z indicates the severity of statewide drought events (low value = severely dry). The US Climate Extremes Index measures the area of nine interstate regions that are subject to extreme weather events. Wildfire identifies the top ten states that experienced wildfires in a given year based on the impacted area. Cases and deaths measure the number of COVID-19 infections and deaths per 100,000 state inhabitants. Mask mandates measure the fraction of state inhabitants affected by mask mandates (based on county-level mask mandates). Skeptical and Leaders identify states where less (or more) than the median fraction of the population is vaccinated at least once, considering weekly data. CEI, Climate Extremes Index; FE, fixed effects; SVI, Search Volume Index. Significance levels: * $p < 0.1 \geq 0.05$, ** $p < 0.001$.

Models (5) and (6) regressed different metrics that indicate the severity of the COVID-19 pandemic on our measure of weather-independent climate change interest (i.e., changes in the SVI that are not affected by current weather conditions). Weather-independent climate change interest results from orthogonalizing SVI of climate change on various measures of weather conditions and extremes (specifications 1 and 2). A negative association between COVID-19 deaths (−0.0207) and weather-independent climate change interest was identified. Furthermore, there was a strong positive association between the variable leaders and weather-independent climate change interest (3.3580).

4. Discussion

This study provides an approach for identifying drivers of public interest in climate change by examining US state-level panel data on weather, climate, and COVID-19

pandemic-related empirical data. The results show that current weather conditions and fluctuations of climatic extremes are associated with changes in the SVI on climate change. Hereby, especially temperature anomalies in terms of higher temperatures as usually expected and climate extremes show a positive correlation with search interest in climate change. Moreover, the panel data analysis revealed that in periods of climatic wetness (higher Palmer Z) and higher amounts of precipitation, there was an association with lower information demand in climate change, indicating that especially high temperatures and the narrative of global warming drive search interest in climate change. Similar observations were made by Lang, analyzing the effects of weather fluctuations on the SVI of the combined keyword search 'climate change' and 'global warming' concerning 205 media markets in the US from 2004 to 2013 [26]. While hot spells appeared to be associated with an SVI increase of 0.27% with each additional day above 85 degrees Fahrenheit [29.44 degrees Celsius], an increase in the SVI was also identified in connection with streaks of extreme drought. Matching these results, Choi et al. used the SVI on the topic of 'global warming,' identifying an increase in the SVI when the local temperature was abnormally high in 74 different locations worldwide from 2004 to 2017 [33].

Surprisingly, accounting for unobserved heterogeneity among regional groupings of similar climate environments, there was an association between individuals in states affected by climatic extremes and lower search interest in climate change. Including the CEI in the models may alleviate concerns resulting from omitted variables as it is a measure for a three-month average over regionally grouped US states. The variability in data, however, is reduced when region-fixed effects are included. Hence, the results suggest that climate extremes affect interest in climate change rather positively. However, favorable conditions for wildfires, e.g., severe periods of drought, are captured more granularly within the other model variables (e.g., rain and Palmer Z). However, within the regional cluster of states, higher interest in climate change was associated with states that are subject to most wildfires. This might indicate that a potential perception of the link between climate change and wildfires is driving search interest and demand for additional information when the effects of different media markets are accounted for more strongly. Supporting this hypothesis, a study by Shteyn found that the number of acres burned by wildfires per US state significantly predicted the regional Google search interest for 'wildfire' in 2019 [34]. On the other hand, Lang and Ryder identified a significant increase in the SVI for the queries 'climate change' and 'global warming' in low-risk designated market areas two months after being hit by a major tropical cyclone when examining 202 designated market areas in the US from 2006 to 2012 [35].

Our results also show that the search interest in topics related to COVID-19 was inversely associated with a higher weekly COVID-19-related mortality. One explanation might be that additional information is especially needed in the early phases of infection, indicated by a significant positive relationship between incidence rates and the SVI on COVID-19-related queries [36]. Furthermore, the knowledge of COVID-19 and information supplied by other channels (e.g., media coverage) may have increased during the course of the pandemic [37]. One could also expect the saturation of new information as the pandemic progresses [38]. During the pandemic, provisions mandating masks were installed dynamically and fragmented throughout different legislative districts and areas, including two states (South Dakota and Iowa) that never issued a mask mandate [39,40]. As a result, there was a strong positive correlation between the people affected by mask mandates and the SVI on COVID-19. The positive correlation might stem from the need to be informed about the latest provisions within a certain area. Similarly, a positive correlation was found between the COVID-19 SVI and states where the proportion of individuals vaccinated at least once is below the interstate median. These results suggest that interest in additional information on topics related to the virus (e.g., COVID-19 vaccination) may be especially high before the first vaccination [41]. A strong state-fixed effect was observed. One cause of such severe impact of unobserved heterogeneity among different states might be political orientation and support for political measures taken to contain the pandemic. For example,

a previous study showed that trust in vaccination science differs between Democratic (82%) and Republican supporters (67%) [42]. However, Viswanath et al. found that other individual and social variables affecting COVID-19 vaccination willingness include age, income, education, employment status, and news exposure, and it is important to note that our study design does not allow for causal interpretation [43].

Additionally, this study proposes a novel measure of weather-independent climate change interest. By orthogonalizing SVI on climate change on various variables capturing the weather and climate-specific factors proven to affect the public interest, we introduce a more general measure based on public awareness of climate change. As expected, there were negative associations between COVID-19 mortality and the weather-independent climate change interest. This observation could suggest that the pandemic has temporarily affected the search interest in climate change, as the COVID-19 pandemic was perceived as a more urgent threat, but a qualitative study design would be more suitable to test this hypothesis. Nevertheless, similar public interest alterations in climate change could be observed in other mass media. While from 1 August 2019 to 23 March 2020, a median of 0.25% of all daily Facebook link shares and reshares from US users were related to climate change, the proportion fell to 0.05% between 24 March and 8 August 2020 [44]. On the other hand, Lyytimäki et al. identified a distinctive drop in the number of published articles with the term climate change and related keywords in Finland's most popular newspaper at the start of the COVID-19 pandemic in 2020 [45]. These observations were also reported for environment-related Google search queries at the onset of the pandemic. Souza et al. identified a decline in global search interest for national parks during the first global lockdown period from 11 March 2020 to the end of July 2020, compared with the same periods in 2016 to 2019 [46]. In contrast, Rousseau and Deschacht identified an increase in nature-related queries from 14 March 2020 to 26 April 2020, e.g., for the terms 'birds' (+7.8 SVI points, $p < 0.001$), 'forest' (+6.2 SVI points, $p < 0.01$) and 'nature' (+5.2 SVI points, $p < 0.001$), while environment-related keywords such as 'climate change', 'air pollution,' or 'CO_2-tax' did not change significantly compared with the same periods in 2019 [47]. However, the period studied was significantly shorter compared with our study.

Finally, a severe increase in weather-independent climate change interest for the measure that identifies a high fraction of state inhabitants being vaccinated at least once was observed. This might indicate that people who have been vaccinated at least once are less likely to perceive COVID-19 as a threat to their personal lives [48]. As a result, the focus on other prevailing issues, such as climate change, was no longer deflected by the immediate danger of contracting COVID-19.

This study is limited by its cross-sectional retrospective design, which does not allow for causal interferences. For example, some results suggest that psychological motives lead to alterations in information demand on coronavirus or climate change. Although this study is able to infer interesting patterns in the average association between demand for information and the severity of the COVID-19 pandemic, the causal analysis should be subject to a more extensive and rather experimental study design. Further research is critically needed to investigate such relationships and their potential implications for climate change mitigation and actions. A further limitation of this study is the exclusive use of Google Trends data. Google Trends does not provide absolute figures on specific queries or topics. Inconsistent results can occur when analyzing more extended periods due to the disproportionate growth of search queries and changing user habits. Furthermore, this study examined Google Trends SVI data on topics instead of single queries, capturing the most popular terms and query variations related to COVID-19 and climate change for US states during the first two years of the pandemic. While analyzing single search terms provides more transparency and reproducibility compared with topics, it does not account for the semantics of searches, variations in spelling, languages, synonyms, plural or singular forms, special characters, and produces more unstable results when used for longitudinal analysis [27]. For instance, Sisco et al. identified that the 21st United Nations Climate Change Conference (COP) in 2015 was associated with the highest search volumes for the

queries climate change and global warming between 2015 and 2019 across 41 countries [49]. Furthermore, the two largest climate marches in 2019 led to a 61% increase in the average effect the COP21 had on the search volumes. Hence, when analyzing single queries related to, for example, climate change adaptation and mitigation, which are likely to peak during such events, a consistently low SVI during periods without such events might be observed, as all values are normalized to the point of time with the highest search ratio. Given that these events did not take place for over 1.5 years during the pandemic (COP26 was postponed to late October 2021, and the first global climate strike after the start of the pandemic occurred in September 2021), one could assume a reduced baseline interest in climate change until the third quarter of 2021. However, the SVI for other queries captured in the climate change topic SVI, such as nature, was shown to be higher in the first months of the pandemic compared with previous years [47].

Similarly, focusing on specific COVID-19-related keywords such as COVID-19 vaccines instead of the broader topic of coronavirus disease 2019 can significantly influence the results. Following Merrick et al., the SVI related to vaccine misinformation peaked following Food and Drug Administration authorization and exhibited several spikes after subsequent vaccine announcements [50]. In contrast, search terms seeking general vaccine information mirrored the trend in vaccination uptake in the US. Therefore, the SVI for COVID-19 vaccines prior to the vaccine rollout in December 2020 may have been comparably low, while other terms included in the topic analysis, such as mask mandates or incidence, could have spiked earlier. Thus, analyzing Google Trends topics more accurately reflects the general trend of public interest in broader subjects over time. Future studies might adopt our approach by using different sets of terms to provide a more detailed view of the SVI alteration on specific aspects of climate change.

Finally, it must be noted that the SVI is a surrogate parameter for internet interest. Partial reference is made to non-digital life and social debates in other media, such as newspapers or television, and the non-inclusion of media not available via Google or the underrepresentation of less media-savvy users must be considered. Above all, this study is limited by its geographical focus on a single country. Climate change and the pandemic are issues of global significance, and future research might incorporate global data to improve understanding of these dynamics on a large, international scale.

5. Conclusions

Our results indicate that the public interest in climate change was attenuated by the severity of the COVID-19 pandemic from 2020 to 2022. Furthermore, this study provides a novel measure of weather-independent climate change interest. The measure accounts for weather fluctuations and climate extremes, which have been shown to affect the public interest in climate change systematically. Our weekly panel of US state-level data reveals that the number of weekly new COVID-19-related deaths negatively affected the public's search interest in climate change, while the information demand was greater in states with a higher proportion of Individuals vaccinated at least once. These findings may suggest that the public interest depends on the degree to which climate change is perceived as having an immediate impact on personal living conditions. Hence, the immediate success of initiatives calling for attention to climate change mitigation and adaptation could depend on the degree of urgency the general public attributes to climate change. The following implications might be subject to further research:

1. The success of non-governmental organization marketing measures could be affected by the general awareness of climate change, which may divert as soon as more immediate threats to life and living conditions become apparent.
2. The popularity of political decisions concerning climate change could be affected by the level of awareness the general public imposes on the consequences of climate change.
3. The narrative of global warming may be most reflective of climate change awareness and extreme weather conditions in the general population, as abnormally high tem-

peratures especially correlate with an increase in climate change search interest when regressing weather and climate extremes data.
4. The impact of perceived threats could be a driving factor in the awareness of climate change. Hence, other contemporary and prevailing events (e.g., the Ukraine war) could hinder climate change awareness and education.
5. The analysis of public interest needs to consider current threats, e.g., when examining motivational changes related to climate change (as a way to understand the pattern of unjustified low interest in climate change because of other, more immediate threats).

Author Contributions: Conceptualization, L.H., S.F. and F.B.; methodology, S.F. and F.B.; software, S.F. and F.B.; validation, L.H., K.K.B., J.C., C.R., P.S., J.M., S.F. and F.B.; formal analysis, L.H., S.F. and F.B.; investigation, S.F. and F.B.; resources, S.F. and F.B.; data curation, L.H., S.F. and F.B.; writing—original draft preparation, L.H., S.F. and F.B.; writing—review and editing, L.H., K.K.B., J.C., C.R., P.S., J.M., S.F. and F.B.; supervision, F.B.; project administration, F.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The data that support the findings of this study are openly available in Figshare. Upon publication, the collected and analyzed dataset will be made publicly available under: Hoff-mann, L.; Bressem, K.K.; Cittadino, J.; Rueger, C.; Suwalski, P.; Meinel, J.; Funken, S.; Busch, F. Da-taset: From Global Health to Global Warming: Tracing Climate Change Interest During the First Two Years of COVID-19 using Google Trends Data from the United States. figshare 2023. For review, please refer to the private anonymized link: https://figshare.com/s/e6a6d52aa0d6329c078d (accessed on 1 October 2023).

Acknowledgments: K.K.B. is grateful for his participation in the Berlin Institute of Health (BIH) Charité Digital Clinician Scientist Program, funded by the Charité—Universitätsmedizin Berlin and the BIH.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. IPCC. Climate Change 2022: Impacts, Adaptation, and Vulnerability. In *Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*; Pörtner, H.-O., Roberts, D.C., Tignor, M., Poloczanska, E.S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., Okem, A., Rama, B., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2022; pp. 1–3058.
2. Etkin, D.; Ho, E. Climate Change: Perceptions and Discourses of Risk. *J. Risk Res.* **2007**, *10*, 623–641. [CrossRef]
3. Biesbroek, G.R.; Swart, R.J.; Carter, T.R.; Cowan, C.; Henrichs, T.; Mela, H.; Morecroft, M.D.; Rey, D. Europe adapts to climate change: Comparing National Adaptation Strategies. *Glob. Environ. Change* **2020**, *20*, 440–450. [CrossRef]
4. Moxnes, E.; Saysel, A.K. Misperceptions of global climate change: Information policies. *Clim. Change* **2009**, *93*, 15–37. [CrossRef]
5. Anderson, A. Climate Change Education for Mitigation and Adaptation. *J. Educ. Sustain. Dev.* **2012**, *6*, 191–206. [CrossRef]
6. Shelley, B.; Mireille, L.; David, I. School Strike 4 Climate": Social Media and the International Youth Protest on Climate Change. *Media Commun.* **2020**, *8*, 208–218.
7. Chia, J. Social Media and the Global Climate Strike: A tool for youth climate change activists and politicians. *Sojourners* **2021**, *12*, 12–13.
8. Laux, T. What makes a global movement? Analyzing the conditions for strong participation in the climate strike. *Soc. Sci. Inf.* **2021**, *60*, 413–435. [CrossRef]
9. Bouman, T.; Steg, L.; Dietz, T. Insights from early COVID-19 responses about promoting sustainable action. *Nat. Sustain.* **2021**, *4*, 194–200. [CrossRef]
10. Manzanedo, R.D.; Manning, P. COVID-19: Lessons for the climate change emergency. *Sci. Total Environ.* **2020**, *742*, 140563. [CrossRef] [PubMed]
11. Aalmo, G.O.; Gioli, B.; Rodriguez, D.G.P.; Tuomasjukka, D.; Liu, H.-Y.; Pastore, M.C.; Salbitano, F.; Bogetoft, P.; Sæbø, A.; Konijnendijk, C. Development of a novel framework for the assessment and improvement of climate adaptation and mitigation actions in Europe. *Front. Sustain. Cities* **2022**, *4*, 833098. [CrossRef]
12. Bartoňová, A.; Colette, A.; Zhang, H.; Fons, J.; Liu, H.Y.; Brzezina, J.; Chantreux, A.; Couvidat, F.; Guerreiro, C.; Guevara, M.; et al. *ETC/ATNI Report 16/2021: The COVID-19 Pandemic and Environmental Stressors in Europe: Synergies and Interplays*; European Environment Information and Observation Network, European Environment Agency: Copenhagen, Denmark, 2022; pp. 1–192.
13. Ordóñez, C.; Garrido-Perez, J.M.; García-Herrera, R. Early spring near-surface ozone in Europe during the COVID-19 shutdown: Meteorological effects outweigh emission changes. *Sci. Total Environ.* **2020**, *747*, 141322. [CrossRef]

14. Brancher, M. Increased ozone pollution alongside reduced nitrogen dioxide concentrations during Vienna's first COVID-19 lockdown: Significance for air quality management. *Environ. Pollut.* **2021**, *284*, 117153. [CrossRef]
15. Kumar, P.; Hama, S.; Omidvarborna, H.; Sharma, A.; Sahani, J.; Abhijith, K.; Debele, S.E.; Zavala-Reyes, J.C.; Barwise, Y.; Tiwari, A. Temporary reduction in fine particulate matter due to 'anthropogenic emissions switch-off' during COVID-19 lockdown in Indian cities. *Sustain. Cities Soc.* **2020**, *62*, 102382. [CrossRef]
16. Savin, I.; Drews, S.; van den Bergh, J.; Villamayor-Tomas, S. Public expectations about the impact of COVID-19 on climate action by citizens and government. *PLoS ONE* **2022**, *9*, 17. [CrossRef]
17. Mohommad, A.; Pugacheva, E. *Impact of COVID-19 on Attitudes to Climate Change and Support for Climate Policies*; Working Paper No. 2022/023; International Monetary Fund: Washington, DC, USA, 2022; pp. 1–22.
18. Khojasteh, D.; Davani, E.; Shamsipour, A.; Haghani, M.; Glamore, W. Climate change and COVID-19: Interdisciplinary perspectives from two global crises. *Sci. Total Environ.* **2022**, *844*, 157142. [CrossRef]
19. Jansen, B.J.; Spink, A.; Saracevic, T. Real life, real users, and real needs: A study and analysis of user queries on the web. *Inf. Process. Manag.* **2020**, *36*, 207–227. [CrossRef]
20. Spink, A.; Wolfram, D.; Jansen, B.J.; Saracevic, T. Searching the web: The public and their queries. *J. Am. Soc. Inf. Sci. Technol.* **2001**, *52*, 226–234. [CrossRef]
21. Granka, L.A.; Joachims, T.; Gay, G. Eye-Tracking Analysis of User Behavior in WWW-Search. In Proceedings of the 27th Annual International ACM SIGIR Conference on Research and Development in Information Retrieval, New York, NY, USA, 25–29 July 2004.
22. Pan, B.; Hembrooke, H.; Joachims, T.; Lorigo, L.; Gay, G.; Granka, L. In Google we trust: User's decisions on rank, position, and relevance. *J. Comput. Mediat. Commun.* **2007**, *12*, 801–823. [CrossRef]
23. Epstein, R.; Robertson, R.E. The search engine manipulation effect (SEME) and its possible impact on the outcomes of elections. *Proc. Natl. Acad. Sci. USA* **2015**, *112*, E4512–E4521. [CrossRef] [PubMed]
24. Nisbet, M.C.; Myers, T. The Polls—Trends: Twenty Years of Public Opinion about Global Warming. *Public Opin. Q.* **2007**, *71*, 444–470. [CrossRef]
25. McCallum, M.L.; Bury, G.W. Google search patterns suggest declining interest in the environment. *Biodivers. Conserv.* **2013**, *22*, 1355–1367. [CrossRef]
26. Lang, C. Do weather fluctuations cause people to seek information about climate change? *Clim. Change* **2014**, *125*, 291–303. [CrossRef]
27. Google News Initiative. Google Trends. Available online: https://storage.googleapis.com/gweb-news-initiative-training.appspot.com/upload/Google_Trends.pdf (accessed on 12 February 2023).
28. Jun, S.P.; Yoo, H.S.; Choi, S. Ten years of research change using Google Trends: From the perspective of big data utilizations and applications. *Technol. Forecast. Soc. Change* **2018**, *130*, 69–87. [CrossRef]
29. Eysenbach, G. Infodemiology and infoveillance: Framework for an emerging set of public health informatics methods to analyze search, communication and publication behavior on the Internet. *J. Med. Internet Res.* **2009**, *11*, e1157. [CrossRef]
30. Dey, M.; Zhao, S.S. COVID-19 and Kawasaki disease: An analysis using Google Trends. *Clin. Rheumatol.* **2020**, *39*, 2483–2484. [CrossRef]
31. Statcounter: Search Engine Market Share Worldwide. Available online: https://gs.statcounter.com/search-engine-market-share/all (accessed on 1 December 2023).
32. Karl, T.; Koss, W.J. *Regional and National Monthly, Seasonal, and Annual Temperature Weighted by Area, 1895–1983*; Historical Climatology Series 4-3; National Climatic Data Center: Asheville, NC, USA, 1984; pp. 1–44.
33. Choi, D.; Gao, Z.; Jiang, W. Attention to Global Warming. *Rev. Financ. Stud.* **2020**, *33*, 1112–1145. [CrossRef]
34. Shteyn, M.F. Regional Extreme Weather Concern and its Relation to Support for Environmental Action. Master's Thesis, University of California, Santa Barbara, CA, USA, September 2020.
35. Lang, C.; Ryder, J.D. The effect of tropical cyclones on climate change engagement. *Clim. Change* **2016**, *135*, 625–638. [CrossRef]
36. Zhou, Y.; Li, W.; Wang, D.; Mao, L.; Jin, H.; Li, Y.; Hong, C.; Chen, S.; Chang, J.; He, Q.; et al. Clinical time course of COVID-19, its neurological manifestation and some thoughts on its management. *Stroke Vasc. Neurol.* **2020**, *5*, 177–179. [CrossRef]
37. Ali, S.; Foreman, J.; Tozan, Y.; Capasso, A.; Jones, A.M.; DiClemente, R.J. Trends and Predictors of COVID-19 Information Sources and Their Relationship With Knowledge and Beliefs Related to the Pandemic: Nationwide Cross-Sectional Study. *JMIR Public Health Surveill.* **2020**, *6*, e21071. [CrossRef]
38. Mohammed, M.; Sha'aban, A.; Jatau, A.I.; Yunusa, I.; Isa, A.M.; Wada, A.S.; Obamiro, K.; Zainal, H.; Ibrahim, B. Assessment of COVID-19 Information Overload Among the General Public. *J. Racial Ethn. Health Disparities* **2022**, *9*, 184–192. [CrossRef]
39. Wright, A.L.; Chawla, G.; Chen, L.; Farmer, A. *Tracking Mask Mandates during the COVID-19 Pandemic*; Working Paper No. 2020-104; Becker Friedman Institute for Economics: Chicago, IL, USA, 2020; pp. 1–14.
40. Chen, C.; Boadu, D.B.; Xiao, R. Mask or No Mask for COVID-19? Do the Individual Characteristics of Governors Affect the Adoption of Statewide Public Mask Mandates? *Public Perform. Manag. Rev.* **2022**, *45*, 1214–1234. [CrossRef]
41. An, L.; Russell, D.; Mihalcea, R.; Bacon, E.; Huffman, S.; Resnicow, K. Online Search Behavior Related to COVID-19 Vaccines: Infodemiology Study. *JMIR Infodemiol.* **2021**, *1*, e32127. [CrossRef]
42. Hamilton, L.C.; Hartter, J.; Saito, K. Trust in Scientists on Climate Change and Vaccines. *SAGE Open* **2015**, *5*, 2158244015602752. [CrossRef]

43. Viswanath, K.; Bekalu, M.; Dhawan, D.; Pinnamaneni, R.; Lang, J.; McLoud, R. Individual and social determinants of COVID-19 vaccine uptake. *BMC Public Health* **2021**, *21*, 818. [CrossRef]
44. Spisak, B.R.; State, B.; van de Leemput, I.; Scheffer, M.; Liu, Y. Large-scale decrease in the social salience of climate change during the COVID-19 pandemic. *PLoS ONE* **2022**, *17*, e0256082. [CrossRef]
45. Lyytimäki, J.; Kangas, H.-L.; Mervaala, E.; Vikström, S. Muted by a Crisis? COVID-19 and the Long-Term Evolution of Climate Change Newspaper Coverage. *Sustainability* **2020**, *12*, 8575. [CrossRef]
46. Souza, C.N.; Rodrigues, A.C.; Correia, R.A.; Normande, I.C.; Costa, H.C.; Guedes-Santos, J.; Malhado, A.C.; Carvalho, A.R.; Ladle, R.J. No visit, no interest: How COVID-19 has affected public interest in world's national parks. *Biol. Conserv.* **2021**, *256*, 109015. [CrossRef]
47. Rousseau, S.; Deschacht, N. Public Awareness of Nature and the Environment During the COVID-19 Crisis. *Environ. Resour. Econ.* **2020**, *76*, 1149–1159. [CrossRef]
48. Fischer, I.; Rubenstein, D.; Levin, S. Vaccination-hesitancy and global warming: Distinct social challenges with similar behavioural solutions. *R. Soc. Open Sci.* **2022**, *9*, e211515. [CrossRef]
49. Sisco, M.R.; Pianta, S.; Weber, E.U.; Bosetti, V. Global climate marches sharply raise attention to climate change: Analysis of climate search behavior in 46 countries. *J. Environ. Psychol.* **2021**, *75*, 101596. [CrossRef]
50. Merrick, E.; Weissman, J.P.; Patel, S.J. Utilizing Google trends to monitor coronavirus vaccine interest and hesitancies. *Vaccine* **2022**, *40*, 4057–4063. [CrossRef] [PubMed]