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Discussing climate change online. Topics and perceptions in online climate change communication in different online public arenas

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Abstract

How users discuss climate change online is one of the crucial questions (science) communication scholars address nowadays. This study contributes by approaching the issue through the theoretical concept of online public arenas. The diversity of topics and perceptions in the climate change discourse is explored by comparing different arenas. German journalistic articles and their reader comments as well as scientific expert blogs are analyzed by quantitative manual and automated content analysis ($n = 5,301$). Findings demonstrate a larger diversity of topics and interpretations in arenas with low barriers to communication. Overall, climate change skepticism is rare, but mostly present in lay publics.

Keywords

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

Introduction

The advent of the Internet has offered the chance to foster participation through augmented possibilities for citizen activity [Dahlberg, 2001; Goldberg, 2011]. The Internet provides various opportunities, among which are access to a wealth of information, low barriers to public discourses, possibilities to interact with others and new ways of participation [Papacharissi, 2002]. Thus, a lot of research has already focused on the deliberative potential of online communication. Studies have shown that the Internet does, in fact, increase the citizenry's level of political participation, though this is limited primarily to people interested in political issues [e.g. Min, 2010].

It has also been highlighted that the Internet holds great participatory potential for science communication [O'Neill and Boykoff, 2011]. Manifold ways of becoming active and engaged exist online: laypeople can not only inform themselves about scientific topics more easily, but they can also produce, distribute and communicate scientific information themselves [Bowman and Willis, 2003; Koteyko, Nerlich and Hellsten, 2015]. These possibilities meet the new paradigm of public engagement in science communication, which claims active citizen participation in the scientific discourse [Durant, 1999; Irwin and Wynne, 1996; Stilgoe, Lock and Wilsdon, 2014].

However, thus far we still know too little about how laypeople actually participate — that is communicate — in online discourses on scientific issues compared to

journalists and scientists [Schäfer, 2016; Williams et al., 2015]. It is particularly necessary to research the dynamic context of online public spheres. This paper contributes to this area by introducing a theoretically based differentiation of online public spheres — instead of exploring single platforms like Facebook or Twitter. Focusing on Germany as a case, this paper investigates the frequency, topic and manner in which Internet users communicate about one of today's most relevant science topics — climate change.

Climate change and the public

Climate change is one of the biggest challenges facing humanity [Glenn, Gordon and Florescu, 2014]. Accordingly, it has been a topic in the mass media for some time [Boykoff, 2010] and its media attention worldwide is still increasing [Schmidt, Ivanova and Schäfer, 2013]. The mass media play a crucial role in communicating climate change to the public [von Storch, 2009]. On the one hand, climate change is an abstract and complex topic which has to be "scaled-down" to people's everyday lives; on the other hand, its scientific findings are often uncertain and even sometimes conflicting [van der Sluijs, 2012].

Thus, much of the research has focused on journalistic coverage [for an overview see Schäfer and Schlichting, 2014]. Different aspects of climate change can be covered by journalists; e.g. scientific, political, and economic aspects. Furthermore, they might present different levels of certainty on climate research findings, for example results on the human-made causes or negative consequences of climate change. However, journalists seem to focus on the scientific consensus on anthropogenic climate change and the IPCC report [Brüggemann and Engesser, 2014; Painter and Ashe, 2012]. It is assumed that journalistic representations are mainly reflected in public perceptions. Survey research on the public's perception of climate change supports this assumption, because it has generally indicated that the majority of the public is convinced that anthropogenic climate change is legitimate [Poortinga et al., 2011].

However, significant national differences regarding media reporting and public perception exist [for an overview see Antilla, 2010; Engels et al., 2013; Grundmann and Scott, 2014; Nerlich, Forsyth and Clarke, 2012]. In the United States and Great Britain [Painter and Ashe, 2012], for example, the public discourse is polarized and the mass media overemphasize climate skeptical statements [Boykoff and Boykoff, 2004]. This is in stark contrast to Germany, which is exceptional for its strong consensus on the issue of anthropogenic climate change. In the case of Germany, journalists emphasize consensus rather than conflict [Schäfer, 2016]. They primarily represent the scientific arguments of the IPCC reports [Peters and Heinrichs, 2008]. Moreover, they tend to exaggerate the certainty of scientific findings [Maurer, 2011]. This corresponds with a relatively small segment of German climate change skeptics [Engels et al., 2013; Rückert-John, Bormann and John, 2013].

However, one of the urgent questions nowadays is how climate change is discussed online where low barriers to communication allow contributions from laypeople deviating from the consensus on anthropogenic climate change in journalistic media.

State of research: online climate change communication

From the user's perspective, the Internet is a massive and easily available source of scientific information. In Germany, about two thirds of the population seek online for information on scientific issues at least occasionally [Wissenschaft.im.Dialog, 2015]. Internet usage was found to be positively related with knowledge about climate change [e.g. Eurobarometer, 2011; Zhao, 2009], the need for information on climate change [e.g. Zhao, 2009] and with that, also problem awareness and behavioral intentions [e.g. Taddicken, 2013] — although statistical indicators are often small. This is hardly surprising as online content on climate change is very diverse. Firstly, this is true regarding the platform or website: online climate change communication can be found in online news media and their user comments, scientific blogs, discussion forums, political or civil society websites and social networking sites [O'Neill and Boykoff, 2011]. Secondly, the diversity of online communicators is very broad: from scientists and laypeople to mass media organizations, politicians, corporations and NGOs [Schäfer, 2012]. Overall, user-generated content constitutes a crucial part of the climate change communication online.

Accordingly, also very diverse topics were found in the English-speaking online discourse on climate change, primarily focused on scientific evidence [Collins and Nerlich, 2015; Ladle, Jepson and Whittaker, 2005; Sharman, 2014]. For example, several Twitter studies during the IPCC report's release in 2013 found much communication on scientific aspects [Newman, 2016; O'Neill et al., 2015; Pearce et al., 2014], but also hashtags related to political campaigns, geographical discussions, climate protection, and innovative technologies [Pearce et al., 2014]. Kirilenko and Stepchenkova [2014] analyzed the Twitter discourse for two years and found, in particular, topics from journalistic media like climate summits, the IPCC report and extreme weather events. Koteyko, Thelwall and Nerlich [2010] explicitly investigated the online discourse on climate change mitigation and also detected very diverse (carbon-related) sub-topics such as finance, lifestyle, and attitudes.

Considering that scientific evidence on climate change is a major topic in online discourses, it comes as no surprise that the existence of climate change is often discussed online as well [Schäfer, 2012; Taddicken, 2013]. Several studies indicate differences in the perception of climate change between the users' online discourse and journalistic media. Reader comments of British and Dutch online newspapers were found to be mostly climate change skeptical [Collins and Nerlich, 2015; De Kraker et al., 2014; Jaspal, Nerlich and Koteyko, 2013; Koteyko, Jaspal and Nerlich, 2012]. Also a number of other studies prove significant climate change skepticism as well as critiques of climate science to be widespread within online communication and particularly social media platforms [English web feeds: Gavin and Marshall, 2011; Koteyko, 2010; Koteyko, Thelwall and Nerlich, 2010; Ladle, Jepson and Whittaker, 2005; blogs: Lockwood, 2008; Sharman, 2014; YouTube: Porter and Hellsten, 2014]. Jang and Hart [2015] identified country-specific discourses on Twitter and found more skeptic frames in the US than in other countries.

Two Twitter studies around the IPCC report 2013 contrast with these climate skeptic results: Pearce et al. [2014] found most users — especially journalists, scientists and activists — to be supportive of climate science and policies. According to O'Neill et al. [2015], Twitter communication is less climate change

skeptical than mass media coverage in the UK and the US, contains more emphasis on the broad expert consensus, and highlights the need for action.

These conflicting findings have to be seen within the context of their inquiry period. Many of these studies were conducted during the Climategate affair, which might have resulted in a higher level of climate change skepticism for that time period [Holliman, 2011].

To summarize: research findings on climate change communication online are heterogeneous. One of the major challenges so far is that many studies focus on single online platforms, e.g. Twitter. They lack consideration of different forms of online communication and with this different constellations of communicators — even within the same platform. It remains unclear whether topics and interpretations differ between platforms and, if so, to what extent. Moreover, theory-based studies are difficult to come by. These limitations are remedied here. The present study aims to analyze how various forms of online communication differ in the diversity of topics and interpretations. For this, the theoretical concept of online public arenas [Schmidt, 2013] is applied. This is done within the German context where online communication on climate change has hardly been analyzed yet [Schäfer, 2016].

Theory: online public arenas

The public sphere is a social forum where citizens come to an understanding about common issues [Habermas, 1962/1989]. In modern societies, the public sphere can be differentiated into *encounter public* with interpersonal communication between citizens in public places, *event public* such as public lectures or town hall meetings and *mass media public* [Gerhards and Neidhardt, 1993]. With the rise of the Internet, the concept of differentiated public spheres has been reconsidered and needs to be refined. The constitution of a public sphere is interdependent on communication technology and communication modes [Schmidt, 2013]. New modes of communication featuring characteristics of interpersonal and mass media communication allow for an intermingling and integration of the different partial public spheres.

Schmidt's [2013] concept of online public arenas takes these dynamics into account. Schmidt [2013, p. 41, own translation] defines public arenas as "specific constellations of agents (communicator and audience) [. . .], who offer information on the basis of particular rules of selection and presentation as well as a specific software architecture". Similar to Gerhards' and Schäfer's [2010] adaptation of the partial public spheres to the online environment, the arenas differ with regard to their barriers to communication, their intended audience and their goals of communication. Schmidt [2013] distinguishes between (1) *mass media arena*, and (2) *expert arena*. The mass media arena has high barriers for communication, is monological and directed to a dispersed, anonymous audience, as seen on journalistic websites. Communicators have to abide by journalistic norms; they are usually journalists or external authors whom the editorial team has engaged. The expert arena also has high barriers for communicators, often due to professionally specialized discourses. It may allow dialogue with its expert community audience, such as that found in scientific journals or expert blogs. The high barriers to communication in the mass media and expert arena are sometimes not explicitly

mentioned, but exist de facto. Moreover, contributions are restricted by the editorial line or scientific principles.

Expanding on this concept, another arena seems relevant for investigating lay public participation online: (3) the (*mass-media-induced) discussion arena*. This arena is characterized by low barriers to communicate dialogically to an audience that has not been further specified. Laypeople may exchange their views and opinions here. A widespread form of the discussion arena is the mass-media-induced discussion arena: a discussion arena with initial journalistic input (e.g. user comments on online news media).

Hypotheses on the climate change discourse in online public arenas

Discourses about the implications of the Internet on the constitution of public spheres raise two overall assumptions that are crucial for investigating topics and interpretations in online climate change communication: the assumption that the Internet allows (1) more plurality of topics and opinions [Gerhards and Schäfer, 2010] and that this leads to a (2) fragmentation of the public sphere(s) [Sunstein, 2001].

(1) Due to the diverse public agents communicating online, a broad spectrum of climate change related topics and opinions might be found online. However, the level of plurality presumably depends on the barriers for communication. Significant plurality of communicated topics — which previous studies have found — can be assumed in arenas with low barriers for communication such as the mass-media-induced discussion arena. It is expected that the mass media arena covers more political aspects of climate change due to its function in communicating societally relevant information, as compared to the expert arena and its more scientific discourse.

> *H1: The level of plurality of topics in the mass-media-induced discussion arena is higher than in the other online public arenas.*

However, causes and consequences of climate change as well as mitigation and adaptation measures might be more often discussed in the mass media arena, as its mission is to spread societally relevant information.

> *H2: Causes and consequences of climate change as well as mitigation and adaptation measures are rather mentioned in the mass media arena as compared to other online public arenas.*

The mass media and expert arena are assumed to cover the consensus on anthropogenic climate change. As climate change skepticism is barely represented in the German journalistic media, certain online public arenas may be an "alternative" platform for climate change skeptics [Taddicken, 2013]. As discussed earlier, many studies have found substantial skepticism online. This is particularly to expect in mass-media-induced discussion arenas that have low barriers to communication and thus allow for expressing "deviant" opinions that are not represented in the mass media and expert arena.

H3: There is a more climate change skeptical discourse in the mass-media-induced discussion arena than in other online public arenas.

Different strategies to express climate change skepticism exist, such as emphasizing scientific uncertainty and denigrating climate science [Jaspal, Nerlich and Koteyko, 2013; Koteyko, Jaspal and Nerlich, 2012]. Thus, to what extent climate science is considered to be (un)certain and (not) credible is examined. More critical interpretations are expected in the mass-media-induced discussion arena due to low communication barriers.

H4: In the mass-media-induced discussion arena, climate science is presented as more uncertain (H4a) and not credible (H4b) as compared to other online public arenas.

(2) Two different perspectives exist on the integration of the public sphere(s) on the Internet: on the one hand, Hale [2012] and Sams and Park [2014] stress its interconnection through hyperlinks. On the other hand, Sunstein [2001] detected that the Internet is fragmented into many isolated partial public spheres with their own topics and interpretations. From a normative perspective, a fragmentation of the climate change discourse is problematic as societies need common discourses in order to negotiate how to deal with climate change [Habermas, 2008].

Twitter studies on climate change found users segregated into like-minded communities and few mixed-attitude communities [Edwards, 2015; Williams et al., 2015]. In contrast, other Twitter studies have found the mass media to be the most important communication trigger, reference and influencer in terms of retweets [Kirilenko and Stepchenkova, 2014], and source [Newman, 2016; Veltri and Atanasova, 2015]. Hence, topics and interpretations in the mass-media-induced discussion arena are presumably related to the corresponding articles. Its communicators are also audiences of the journalistic coverage that processes the content actively [Hall, 1973; Morley, 1992].

H5: Topics and interpretations in the mass media, expert and mass-media-induced discussion arena overlap.

Method

To analyze the hypotheses, a quantitative manual and automated online content analysis was conducted in three different online public arenas in the German language. The combination of manual and automated coding via machine learning enabled a full data analysis of complex content-related variables.

The inquiry period spanned from one week prior until one week after the release of the IPCC report WG1 (2013/09/16–2013/10/07). The IPCC report is regarded as the most crucial scientific publication on anthropogenic climate change and reflects the current state of climate science [Hulme, 2009; IPCC, 2013]. Therefore, it triggers high levels of public attention.

In a conscious case selection [Flick, 2007], at least two websites with regular activity for all three arenas in Germany were selected. The selection of mass media platforms was based on the amount of user-traffic. Articles from *Spiegel.de* and

Welt.de were chosen as mass media arenas and their user comments as mass-media-induced discussion arenas, as both outlets have a high reach compared to other online news websites [IVW, 2016]. [1] *Spiegel.de* is considered rather liberal, whereas *Welt.de* is supposed to represent more conservative positions across the German quality media landscape. Furthermore, both outlets have a comparatively active online user community with many reader comments submitted, even though users have to register before commenting. Employees of *Spiegel.de* and *Welt.de* moderate both comment sections by deleting or editing, among others, discriminating, insulting, or illegal comments [Spiegel.de, 2016; Welt.de, 2016]. Two scientific expert blogs were chosen as expert arenas: both *Klimazwiebel* and *Klimalounge* are maintained by renowned climate scientists with distinct viewpoints on the role of climate science. Von Storch (Klimazwiebel) aims at discussing climate science itself and its interrelation with policy debates, whereas Rahmstorf (Klimalounge) aims at enhancing the public's understanding by explaining climate scientific findings comprehensibly. The blogs' administrators check new posts before publication and moderate comments. The "netiquette" is only explicitly mentioned for *Klimazwiebel*: insults, lengthy tirades, ongoing repetitions and amateur-theories are forbidden and the comment must refer to the blog post or discussions [Klimazwiebel, 2016].

A search string with climate change-related keywords was developed to crawl articles and posts in German together with their comment threads: climate change, global warming, climate, IPCC report, IPCC, climate summit, COP, climate policy, climate protection, greenhouse effect, greenhouse gas, carbon (dioxide) (German synonyms of the terms were also used.). The archiving was conducted by a web-crawler developed for this research project and controlled manually before the data collection. Irrelevant articles or initial posts were later eliminated by manual checks. Only text was analyzed. Every article, comment or post was coded as a separate communication unit. In total, the material aggregated to 5,301 units of investigation (see Table 1).

Table 1. Web portal frequencies.

Arena	Web Portal	Frequency of communication units (e.g. article, post, comment)	Systematic Random Sampling (for manual coding)
Mass Media Arena	Spiegel.de	23	23
	Welt.de	18	18
Expert Arena	Klimazwiebel	7	7
	Klimalounge	54	54
Mass media-induced	Comments Spiegel.de	4158	436
Discussion Arena	Comments Welt.de	1041	167
Total		5301	705

The codebook was validated on the basis of the data and was pretested and improved in several coder trainings. As the first step of manual coding, a systematic random sampling was drawn if the comment frequencies exceeded 20 comments per initial post. It was subdivided according to the comment frequency succeeding an initial article or post. For 21−50 comments per initial post, every

[1] *Spiegel.de* with 10,73, *Welt.de* with 9,26 Mio unique users as of March 2014.

fifth comment was analyzed, while if there were more than 50 comments every tenth comment was selected. Systematic random sampling was applied to the reader comments of *Spiegel.de* and *Welt.de*. A team of five researchers coded manually 705 communication units (see Table 1).

In a second step, on the basis of the manual coding, an automated content analysis via machine learning was conducted to achieve full data analysis also for the reader comments of *Spiegel.de* and *Welt.de*. For this, RTextTools were applied according to Jurka et al. [2013] . For every variable, the reliability values (Holsti's [1969] method) for manual and automated coding as well as key figures for the machine learning are documented and explained in Table 2. Following Wimmer and Dominick [2013], the reliability values are on a good or at least acceptable level (manual coding: 0,74–0,98; automated coding: 0,72–0,96). Due to full data analysis, no inferential statistics are needed [Healey, 2014].

To analyze the hypotheses, the following variables were measured:

H1. A multiple-response set was used for the topics explicitly mentioned and related to climate change in the text: politics, science, economy, media/culture/arts/celebrity (e.g. movies about climate change), citizen activity (e.g. activities from civil society or individual citizens), IPCC report as well as topics without reference to climate change. For every unit, a maximum of three topics could be coded — i.e. the three substantial aspects that are discussed the longest or are most important for the argumentation.

H2. Mentions of the causes and consequences of climate change, and climate change mitigation and adaptation measures were measured.

H3. Climate change skepticism was defined according to Rahmstorf [2004] as doubts in the (1) existence of climate change, (2) its human-made causes and (3) its problematic consequences. Thus, mentions and perceptions of these dimensions were measured.

H4. Here, doubts about the certainty and credibility of climate science were investigated as separate dimensions. It was measured if climate science was perceived as (un)certain (H4a) and (not) credible (H4b). Uncertainty could be expressed by describing the findings of climate science as uncertain or conflicting as well as by describing climate science as divided or contradictory. Lack of credibility was coded when communicators explicitly distrusted climate scientists or accused them of being biased because of personal ideology, personal interests, dishonesty, incompetence or being influenced by political and economic interests. In addition, explicitly mentioned certainty and credibility were coded.

Table 2. Reliability values.

Variable	Reliability Manual Coding (Holsti)	Reliability Automated analysis with manual coding (Holsti)[a]	Classification Performances	F-score[b] (mean of manifestation = 0 and manifestation = 1)
Politics and Climate Change	0.82	0.78	RF [Liaw and Wiener, 2002]	0.76
Science and Climate Change	0.87	0.77	RF [Liaw and Wiener, 2002]	0.77
IPCC report	0.97	0.96	GLMNET [Friedman, Hastie and Tibshirani, 2010, p. 7]	0.82
Economy and Climate Change	0.90	0.88	Probability[c]	0.74
Media/Culture/Arts/ Celebrity and Climate Change	0.90	0.85	MAXENT [Jurka, 2012]	0.66
Citizen Activity and Climate Change	0.98	0.86	MAXENT [Jurka, 2012]	0.57
Topics without reference to climate change	0.84	0.80	SVM [Meyer et al., 2012]	0.62
Causes	0.84	0.77	Consent[d]	0.68
Consequences	0.79	0.83	Consent[d]	0.77
Mitigation/Adaptation Measures	0.90	0.72	Consent[d]	0.71
Climate Skeptic Discourse	0.86	0.85	RF [Liaw and Wiener, 2002]	0.73
Existence of climate change	0.74	0.74	GLMNET [Friedman, Hastie and Tibshirani, 2010, p. 7]	0.68
No existence of climate change	0.89	0.91	BOOSTING [Tuszynski, 2012]	0.60
Existence of anthropogenic climate change	0.86	0.78	RF [Liaw and Wiener, 2002]	0.69
No existence of anthropogenic climate change	0.92	0.90	Consent[d]	0.65
Climate science	0.87	0.83	RF [Liaw and Wiener, 2002]	0.77
Certainty of climate science	0.89	0.93	Probability[c]	0.62
Uncertainty of climate science	0.85	0.85	GLMNET [Friedman, Hastie and Tibshirani, 2010, p. 7]	0.65
Credibility of climate science	0.88	0.82	MAXENT [Jurka, 2012]	0.60
Lack of credibility of climate science	0.92	0.86	GLMNET [Friedman, Hastie and Tibshirani, 2010, p. 7]	0.67

[a] Mean of 2 reliability values: 1. Automated analysis with the majority decision of the coding from the manual coding reliability test. 2. Automated analysis with a test set of 500 manually coded units (that were excluded from the manual coding for the machine learning).
[b] [F = 2*(precision*recall)/(precision+recall)].
[c] probability: combined probability of the results of the classification performances.
[d] consent: agreement of the majority of the classification performances.

Results

7.1 Plurality of topics (H1)

In line with other research [Collins and Nerlich, 2015; Pearce et al., 2014; Sharman, 2014], climate change is most frequently a scientific issue (see Table 3). The topic "science and climate change" includes manifold contributions on climate scientific findings — e.g. causes like fossil fuels and consequences like rising sea levels —, but also on climate science and scientists per se. Many of these contributions discuss scientific evidence for anthropogenic climate change: *"Climate change goes on. Here, I agree with Mr. Scientist because we live at the end of a long-lasting ice age. Earth will naturally heat up"* (user 1).

However, science is only the third most frequently discussed topic in the mass media arena (22%). This arena covers the IPCC — a hybrid category between science and politics — more than the others (49%). In addition, climate policy (39%) is far more frequently communicated here.

Science is the most frequent topic in the expert arena (with 54% percent of the communication being on scientific aspects and 30% on the IPCC report) and also in the mass-media-induced discussion arena (37%). Users comment more often about scientific evidence than the initial articles, but far less frequently about climate policy (11%) and the IPCC report (10%). Generally, a higher level of plurality in the mass-media-induced discussion arena (H1) becomes apparent in communication about citizen activity; e.g. individual carbon-friendly behavior, as well as economic aspects (both 16%). Furthermore, there is a large amount of contributions with no reference to climate change (17%). Users seem to associate topics such as clean power or new technologies with climate change without referring to the phenomenon itself. However, it is inherent to (online) discussions that communicators do not refer explicitly to the topic in all of their contributions. More importantly, many issues like nuclear disasters, the ozon hole, use of fertilizers or river deepenings come up that are not related to climate change from the "expert's" point of view and were therefore not captured with the standardized codebook. People try to apply this complex phenomenon to their daily life by blending it with other environmental problems [Lörcher, 2017].

Table 3. Topic frequencies in different online public arenas (in %).

Topics	Mass Media Arena	Expert Arena	Mass media-induced Discussion Arena
	N=41	N=61	N=5199
Science and Climate Change	22	54	37
Politics and Climate Change	39	2	11
IPCC Report	49	30	10
Media/Culture/Arts/Celebrity and Climate Change	5	16	13
Citizen activity and Climate Change	7	2	16
Economy and Climate Change	10	0	16
Topic without reference to Climate Change	2	5	17

Note: Multiple response set, 3 options.

In summary, climate change is mainly a scientific issue, although it is also a political issue in the mass media arena. There is a greater plurality of topics in the mass-media-induced discussion arena, which is also recognizable by the significant amount of communication made without reference to climate change. *H1* is confirmed.

7.2 Causes, consequences, mitigation and adaptation measures (H2)

H2 is also confirmed: causes of climate change, its consequences as well as mitigation and adaptation measures are most frequently mentioned in the mass media arena — in more than two-thirds of the articles (see Table 4). In the expert arena, consequences are mentioned in 39%, causes in 20%, and mitigation and adaptation measures in only 7% of the communication. An explanation for this might be a consensus on the anthropogenic causes of climate change, which is why the focus is rather on actual scientific results regarding consequences. Mitigation and adaptation measures might be regarded as politics and society issues. In the mass-media-induced discussion arena, causes and consequences (both 5%) as well as mitigation and adaptation measures (6%) are also hardly discussed.

Table 4. Mention of causes, consequences and mitigation/adaptation measures (in %).

Mention	Mass Media Arena N=41	Expert Arena N=61	Mass media-induced Discussion Arena N=5199
Causes	68	20	5
Consequences	61	39	5
Mitigation/Adaptation Measures	71	7	6

As assumed, causes, consequences and mitigation/adaptation measures are mentioned in the majority of the mass media articles and far less in other arenas. This might be explained by the journalistic aspiration of delivering extensive information. In the expert arena, discussions within the science community have moved from the causes to the consequences of climate change.

7.3 Climate change skepticism (H3)

For hypotheses H3 and H4, results of the mass-media-induced discussion arena are differentiated for both of the analyzed websites (*Spiegel.de* and *Welt.de*) (see Tables 5–6). The communication within this arena differs significantly between the websites for some categories, presumably because of their different editorial guidelines.

The existence of climate change, its human-made causes and evaluations of its consequences are mentioned in the vast majority of mass media contributions — other arenas refer to these aspects far less (see Table 5).

H3 can be confirmed, as most climate change skepticism was found in the mass-media-induced discussion arena. Looking at mean values, communicators of the mass media and expert arena are convinced of anthropogenic climate change and its negative consequences. This also holds true for user comments of *Spiegel.de*,

only the *Welt.de* comments are more skeptical about the human-made causes and negative consequences. However, the high standard deviation in the mass-media-induced discussion arena indicates large variations in the perception of climate change (see Table 6).

Table 5. Mention of climate change and climate science (in %).

Mention	Mass Media Arena	Expert Arena	Mass media-induced Discussion Arena		
			MDA Total	Spiegel Comment	Welt Comment
	N=41	N=61	N=5199	N=4158	N=1041
Existence climate change	88	39	37	37	38
Anthropogenic climate change	68	21	9	10	7
Evaluation of consequences	58	13	2	2	1
Climate science	37	59	20	21	14
If climate science mentioned:	N=15	N=36	N=1021	N=876	N=145
(Un)certainty	87	28	53	52	57
(Lack of) credibility	33	25	55	52	70

Table 6. Perception of climate change and climate science (Mean value).

Evaluation	Arena Total	Mass Media Arena	Expert Arena	Mass media-induced Discussion Arena		
				MDA Total	Spiegel Comment	Welt Comment
	Valid N	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
Existence climate change	2000	0.9 (0.2)	0.9 (0.5)	0.6 (0.7)	0.6 (1)	0.6 (0.7)
Anthropogenic climate change	517	1.0 (0.2)	0.8* (0.6)	0.8 (0.6)	0.9 (0)	0.5 (0.8)
Evaluation consequences	113	−1.0 (0.2)	−0.9* (0.4)	−0.80 (0.6)	−0.8 (1)	−0.5* (0.8)
(Un)certainty Climate Science	560	0.2* (0.7)	−0.2* (0.9)	−0.5 (0.8)	−0.5 (1)	−0.6 (0.7)
(Lack of) credibility Climate Science	574	1.0* (0)	0.6* (0.9)	-0.2 (0.9)	-0.1 (1.0)	-0.4 (0.8)

Note: M = Mean value; SD = Standard Deviation
Mean values existence (anthropogenic) climate change: −1 =denial, 0=balanced, 1=conviction.
Mean values evaluation consequences: −1 =negative, 0=balanced, 1=positive.
Mean values uncertainty: −1 =uncertain, 0=balanced, 1=certain.
Mean values credibility: −1 =not credible, 0=balanced, 1=credible.
*Valid N<20.

In summary, the mass media arena raises the issues existence and anthropogeneity of climate change far more than the other arenas. It is to assume that the overall agreement is even higher as only explicit mentions were counted here. Climate change skepticism appears almost exclusively in the mass-media-induced discussion arena.

7.4 (Un)certainty and (lack of) credibility (H4)

When climate science is mentioned, almost nine out of ten mass media contributions refer to its (un)certainty. In the mass media induced discussion arena, more than every second user contribution mentioning climate science is also on (un)certainty. Interestingly, this is different in the expert arena (28%).

When climate science is mentioned, (a lack of) credibility is raised less in the mass media (33%) and expert arena (25%) than in the mass-media-induced discussion arena (55%) (see Table 5). Thus, the (lack of) credibility of climate science is rather a discourse of laypersons — whereas (un)certainty is communicated more often by journalists.

Focusing on means (see Table 6), it becomes evident that journalistic articles and experts contributions interpret the certainty of climate science ambiguously, while they perceive climate scientists as credible. *H4* can be confirmed: the mass-media-induced discussion arena perceives climate science as more uncertain (H4a) and less credible (H4b) than the other arenas. However, climate science is perceived as uncertain in all arenas (although only in the minority of mass media articles), e.g. because conflicting scientific results are presented or the uncertainty of climate models is brought up — but not to underline climate skeptic arguments: *"Climate models cannot consider spontaneous events like volcanic eruptions IN ADVANCE, but only afterwards. Thus, short breaks in temperature increase can also occur in the future without being forecasted. But it won't change the trend in the long run"* (user 2). In contrast, climate science is only considered as not credible in the mass-media-induced discussion arena — the differences between the arenas here are larger. Climate scientists are often accused of being influenced by political or economic interests: *"Many climate scientists received only external funds with the premise to conduct alarmist studies"* (user 3). Again, *Welt.de* comments consider climate science as more uncertain and less credible when compared to *Spiegel.de* comments.

In summary, journalists refer especially to the uncertainty frame, while laypeople comment on uncertainty and lack of credibility. Certainty and credibility of climate sciences are often questioned in the user contributions. The communication in the other arenas is less critical, but uncertainty of climate science is nonetheless present. However, not communicating explicitly on (un)certainty might suggest that certainty is taken for granted. Hence, it is striking that certainty is that often expressed.

7.5 Fragmentation of online public arenas (H5)

Although the presented results show significant differences with regard to the topics as well as the perception of climate change and climate science, *H5* can be overall confirmed: topics and interpretations overlap in different online public arenas. The findings indicate that the online public arenas share similar topics with science as a dominant frame. They also share similar perceptions with rather few climate change skepticism and doubts in the certainty of climate sciences. As the mass media arena triggers communication in the mass-media-induced discussion arena, this is hardly surprising. However, it is remarkable that user comments often

cover different topics than the initial article and even discuss topics without relation to climate change.

In summary, on a general level, the topics and some perceptions of climate change and the uncertainty of climate science overlap in the different online public arenas. However, in detail, every arena has also its own specific topics and positions.

Discussion and conclusions

The aim of the study was to investigate how laypeople, journalists, and scientists actually participate — that is communicate — in German online discourses on climate change. An analysis was conducted to determine how the communicated topics and perceptions differed between online public arenas.

The study partly confirms the findings of former studies that climate change is mainly discussed as a scientific issue. However, results show arena-specific differences in online communication. There is a greater diversity of topics in the mass-media-induced discussion arena. This is further underpinned by the significant amount of communication without direct reference to climate change. Thus, discussions seem to be sometimes led "off-topic": users associate diverse topics with climate change that are not directly related to it from the "expert's" point of view, e.g. nuclear disasters or the ozon hole. It can be argued that laypeople communicate "creatively" about climate change and refer to topics that might go beyond the journalistic and expert framing. Topics of user comments often differ substantially from the topic of the initial journalistic article. In other words: laypeople have their own way of "down-scaling" the scientific issue climate change to their lives. Thus, public discourse is provoked by journalists, but follows different patterns of perception.

The existence of climate change, its causes, consequences, mitigation, and adaptation measures are predominantly discussed in the mass media arena — possibly due to the journalistic aspiration of delivering extensive information [Post, 2013]. Moreover, it might be an effect of the length of mass media articles compared to user comments. Most user comments do not discuss the existence of climate change — this contradicts the assumption that the existence of climate change is often discussed online [Schäfer, 2012].

In general, German online climate change communication reflects the consensus on anthropogenic climate change. Most climate change skepticism, which means doubts about the existence of climate change, the human-made causes and its negative consequences, was found in the mass-media-induced discussion arena — more precisely *Welt.de* user comments. This underlines that sometimes laypeople develop their own interpretations beyond journalistic and expert patterns. Overall, the results here show less climate change skepticism than the results from previous studies. This may also be explained by country-specific differences: the German discourse is less skeptical than the Anglo-Saxon discourse which most of the other studies focused on. Moreover, many of the previous studies were conducted during the Climategate affair, which might have provoked a temporarily higher level of skepticism.

However, climate sciences are overall perceived as uncertain. They are described as credible in the mass media and expert arena and as less credible in the

mass-media-induced discussion arena. Thus, many journalists, scientists and laypeople consider (some) findings of climate science as being uncertain, but believe nonetheless in (anthropogenic) climate change. However, the lack of climate science credibility is especially discussed in the mass-media-induced discussion arena and may be used as strategy to cast doubt in the existence of climate change. Future research should therefore remain with this differentiation of climate change skepticism.

The findings show a larger diversity of topics and interpretations in the mass-media-induced discussion arena — laypeople develop their own patterns of perception. Further research on public understanding of and engagement with science should therefore consider the individual reception and appropriation of members of the public and not assume linear relations between journalistic and scientific representations and the public understanding.

Online discussion arenas might be partly used as alternative platforms by people who find their topics of interest and perceptions not represented in the journalistic and expert communication (e.g. climate change skeptics). Still, the discourses of the different online public arenas overlap: journalists, scientists and a (lay) public share similar topics and interpretations, at least on a general level. From a normative perspective, this might be beneficial for a common societal discourse on climate change. However, the Internet provides various platforms for skeptics and therefore opportunities to influence others, which were not analyzed here. As such, it would be valuable to further investigate their arguments, motives, and sources.

Overall, the different findings depending on the online public arena illustrate the imperativeness for future research to differentiate online communication. To analyze, understand and explain the variety of online communication, many differentiations, e.g. between specific applications (like Twitter) or genres (like blogs), often seem not appropriate: different forms of communication may coexist on the same application and genre (e.g. sharing journalistic articles, videos and pictures or chatting with friends on Facebook), or the same forms of communication or content may be found in different applications and genres (e.g. Facebook and Twitter provide the same functionalities such as adding videos). In contrast, the concept of online public arenas is proved here to be sustainable in analyzing different forms of online communication. However, the mass-media-induced discussion arena is heterogeneous and the discourses within this public arena are not consistent. This public arena is characterized by its vast variety, analogous to the encounter public discussed by Gerhards and Neidhardt [1993].

The study at hand has certain limitations. First, results must be considered in view of the inquiry period — the release of the IPCC report. As such, it could have provoked a stronger emphasis on scientific aspects. Future research should compare communication during inquiry periods with "trigger events" from other spheres such as politics.

Furthermore, the standardized design of the study does not allow for a deeper analysis of findings such as the high amount of communication "off-topic" in the discussion arenas. This result might be an outcome of comparing very different material like journalistic articles and user comments with one standardized codebook. User comments often embody implicit statements, which would require

wider coding definitions than those used for journalistic articles. Qualitative approaches would be fruitful to explore the topics in lay communication. The same holds true for investigating the potential fragmentation or overlap of topics and perceptions.

Lastly, only German online climate change communication was analyzed; the results are therefore not generalizable. Comparative analyses with other countries with a more climate-skeptical mass media coverage would be desirable for future research. Moreover, the sampling of the platforms for every arena was not random-based. The most relevant platforms were selected deliberately based on the quantity of traffic and reach.

The results of this study can hopefully be used for future studies, such as analyzing how topics migrate from one arena to another or how the comment culture and interactivity differ between the online public arenas. This would help to understand how different public agents participate in terms of discussing climate change online.

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