



Science and Environmental Communication on YouTube: Strategically Distorted Communications in Online Videos on Climate Change and Climate Engineering

Joachim Allgaier*

Chair of Society and Technology, Human Technology Center (HumTec), RWTH Aachen University, Aachen, Germany

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*Correspondence:

Joachim Allgaier
joachim.allgaier@
humtec.rwth-aachen.de

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The online video-sharing website YouTube is extremely popular globally, also as a tool for information on science and environmental topics. However, only little is known about what kind of information users find when they are searching for information about climate science, climate change, and climate engineering on YouTube. This contribution presents results from an exploratory research project that investigates whether videos found on YouTube adhere to or challenge scientific consensus views. Ten search terms were employed to search for and analyze 200 videos about climate and climate modification topics, which are contested topics in online media. The online anonymization tool Tor has been used for the randomization of the sample and to avoid personalization of the results. A heuristic qualitative classification tool was set up to categorize the videos in the sample. Eighty-nine videos of the 200 videos in the sample are supporting scientific consensus views about anthropogenic climate change, and climate scientists are discussing climate topics with deniers of climate change in four videos in the sample. Unexpectedly, the majority of the videos in the sample (107 videos) supports worldviews that are opposing scientific consensus views: 16 videos deny anthropogenic climate change and 91 videos in the sample propagate straightforward conspiracy theories about climate engineering and climate change. Videos supporting the scientific mainstream view received only slightly more views (16,941,949 views in total) than those opposing the mainstream scientific position (16,939,655 views in total). Consequences for the public communication of climate change and climate engineering are discussed in the second part of the article. The research presented in this contribution is particularly interested in finding out more about strategically distorted communications about climate change and climate engineering in online environments and in critically analyzing them.

Keywords: science communication, environmental communication, YouTube, online video, climate change, climate engineering, geoengineering, conspiracy

INTRODUCTION

Climate change is a grand global challenge that affects the whole of humanity. National solutions alone will not be sufficient to deal adequately with the resulting global problems. Not only political parties, NGOs and industry but also citizens of different backgrounds need to be enrolled in a global public debate about climate change in order to find practical solutions for social, political, economic, and environmental consequences. In order to be able to participate meaningfully it is crucial to argue and discuss on the best scientific evidence base possible. The Intergovernmental Panel on Climate Change (IPCC)¹, working under the auspices of the United Nations, has the aim to provide the world with an objective scientific view on climate change and its social, political, economic, and environmental impacts. One big question, however, is how the scientific evidence base provided by the IPCC reaches the citizens and other stakeholders. The public and political debate around climate change is known to be heavily influenced and often biased and distorted when it comes to the “scientific facts” of climate change. For instance, Oreskes and Conway (2010) have shown in great detail how the science base for climate change and climate experts have gotten under attack from various counter-experts in order to manufacture doubt on the evidence base and the actual experts. It is very difficult to reach informed decisions if the public communication of the scientific consensus view on climate change is being distorted and sometimes portrayed in a way as if there was no scientific consensus. The impacts and consequences of climate change will most likely become even more severe in the near future and climate scientists such as Keith (2013) argue that we must consider deploying climate engineering technologies to slow the pace of global warming and climate change. However, the uses of climate engineering technologies are controversial not just among scientists and also a contentious issue in expert and public discussions. An objective discussion of climate change and the potential application and pros and cons of climate or geoengineering technologies is being hampered by various actors that are either denying climate change or peddling conspiracy theories about climate change and climate engineering. Media coverage shapes discourses and actions on climate change (e.g., Boykoff and Roberts, 2007) and climate engineering (Buck, 2013). While the coverage in journalistic media is overseen by various types of editors that at least theoretically apply some forms of quality control (e.g., Schäfer and Schlichting, 2014) there are no gatekeepers in social online media so that misinformation and incivility can also be found in social media communications about climate change and climate engineering (e.g., Brossard, 2013; Brossard and Scheufele, 2013). It has been reported that the use of online videos and particularly the online video-portal YouTube is on the rise as a global communication and information channel on contemporary issues and that it might potentially be replacing conventional journalistic news channels at some point (e.g., Kalogeropoulos et al., 2016; Haarkötter and Wergen, 2019). For instance, a recent survey by the Pew Research Center (2018) has found that a majority of Americans

across a wide range of demographic groups are YouTube users. Around half (53%) of YouTube users say the site is at least somewhat important for helping them understand things that are happening in the world—with 19% saying it is very important to them for this reason². Online videos have become an important global information source, also for environmental and scientific issues and topics (León and Bourk, 2018). However, so far very little is known about science and environmental information via YouTube and how topics relating to climate change and climate engineering are represented there. The research presented in this contribution has the aim to shed some light on the question if the content that users find on YouTube, when they are searching for information on climate change and climate engineering, will adhere or contradict scientific views on this issue.

SCIENCE AND ENVIRONMENTAL COMMUNICATION ON YOUTUBE

The online video-sharing website YouTube has been a phenomenal success since its launch in 2005. Today YouTube is one of the most popular internet sites and also the second most popular search engine used after Google in many countries (Welbourne and Grant, 2015). It belongs to Alphabet Inc., a holding company that is also the parent company of Google³. According to its self-description YouTube has over a billion⁴ users, almost one-third of all people on the Internet (YouTube, 2018). Many citizens do use YouTube as a source of information about issues concerning science, technology, and medicine (Allgaier, 2016). Research has shown that high reading levels are required to comprehend web-based textual information on science, technology, and medicine (e.g., Berland et al., 2001; Korakakis et al., 2009), and that might be a reason why many people prefer to use and watch YouTube videos in order to find information about scientific and other issues that interest them.

YouTube is particularly popular among young people. For instance, a recent study in Germany found that 94% of youths between 12 and 19 years are familiar with YouTube and that 81% use it regularly (Medienpädagogischer Forschungsverbund Südwest, 2015). Another representative study from Germany (Forum Wissenschaftskommunikation, 2016) found that almost four out of five (78%) of questioned young people between 14 and 29 years said that they use YouTube (and other online video platforms) specifically to get informed about science and research. A recent study from Austria (Artworx, 2015) found that 65% of the YouTube users in Austria use it for learning or getting informed about topics such as science, health and technology. If YouTube is so influential and so many people are using it to get informed about science and research, the big question is what kind of information they find there, for

¹See: <https://www.ipcc.ch/>

²See: www.pewinternet.org/2018/11/07/many-turn-to-youtube-for-childrens-content-news-how-to-lessons/#the-views-and-experiences-of-youtube-users

³See: <https://abc.xyz/>

⁴According to the online statistics portal statista it will be 1.58 billion in 2019 and 1.68 billion in 2020. See: <https://www.statista.com/statistics/805656/number-youtube-viewers-worldwide/>

instance if they are searching for information on climate change or climate engineering.

The video format as such has a great potential for disseminating knowledge, it allows using visual and audio channels in isolation or both combined for transmitting text, images, animations, films, subtitles, multiple languages, and many other innovative and creative means of communication (e.g., Allgaier and Svalastog, 2015). Technically it could be a powerful tool for education and science and environmental communication, but its full potential still needs to be examined and developed (Körkel and Hoppenhaus, 2016). However, so far science and environmental communication on YouTube is still a very under-researched topic (e.g., Allgaier, 2018; León and Bourk, 2018). Welbourne and Grant (2015), for instance, state that it was hard to find any studies that have investigated science communication on YouTube specifically.

Science communication on YouTube is getting increasingly professional. Also science communicators independent of institutional or personal commitments are applying progressively higher standards, for instance concerning aesthetics, and production quality (Muñoz Morcillo et al., 2016). Some science YouTubers, such as *Veritasium*⁵, *VSauce*⁶, or *SciShow*⁷ for instance, reach many million viewers on YouTube and also have millions of subscribers to their video channels (Geipel, 2017, 2018). Lovell (2015) observed: “With hundreds of millions of video views, the new faces of science communication are lighting up the web and reaching more young people than Carl Sagan and Neil deGrasse Tyson combined.” Using YouTube for science and environmental communication has various advantages: it does allow passive consumption of the users, but it also allows building communities and establishing dialogues with various audiences (Erviti and Stengler, 2016).

One important question about science communication on YouTube is whether content created by amateurs in general reaches as much members of the public as content created by professional media organizations. Welbourne and Grant (2015) have found in an empirical study that amateur users that are communicating science via YouTube do not need to fear the professionally generated content made by financially well-equipped organizations. In their sample of YouTube science channels they found that professional media corporations had posted far more videos than the user-generated channels. However, the user-generated channels had significantly more subscriptions and channel views than the professional ones. Therefore, they conclude that YouTube users seem to be happy watching amateur science videos, but their makers need to engage with their audiences.

Another big question concerns the quality of content on platforms such as YouTube. Various studies, mainly from the area of health communication have shown, that the quality of information on YouTube strongly varies and that it is often strongly biased and, from a biomedical or scientific point of view, often inaccurate or erroneous and potentially harmful

(Allgaier, 2018; Haslam et al., 2019). For instance, one recent study compared information about a reported link between MMR vaccination and the development of autism in children, for which there is no scientific evidence, on YouTube, Google, Wikipedia, and the scientific database PubMed (Venkatraman et al., 2015). The study authors assert that from a biomedical point of view the lowest quality of information was found on YouTube and that the factually incorrect information also stayed there for the longest time without being corrected. YouTube is also a notorious Eldorado for conspiracy theories and other highly controversial content, for instance about the Ebola Virus disease (Allgaier and Svalastog, 2015; Basch et al., 2015). One reason for this is that YouTube is a social media site without any quality or editorial control; virtually everybody can open an account and upload content on this platform (Soukup, 2014) and it is also possible to find “nonsensical” contributions that would probably not find their way into mainstream journalistic media (e.g., Michael, 2017).

So far the climate change topic has not received a great deal of attention in research about science and environmental communication on YouTube. For instance, a recent review on climate change in social media (Pearce et al., 2018) has found that so far the research has strongly focused on Twitter and large-scale quantitative textual approaches. The authors argue that future work should embrace smaller scale studies, qualitative approaches, and the inclusion of visual platforms, such as YouTube or Instagram, which remain understudied. So far only little is known about how climate topics are dealt with on online video platforms such as YouTube, despite their global popularity.

Another big question is how climate change has been depicted in online videos and if user generated content is as reliable as that of professional media organizations. Erviti et al. (2018) have examined a sample of online videos on climate change, which were obtained from Google videos, in order to investigate this issue. Their main finding is that they have found evidence for strategically distorted communications in which it is claimed that the scientific debate on climate change is still ongoing and that there is no scientific consensus on climate change: “Climate change remains an issue with a relatively high level of controversy despite the consolidation of scientific consensus around the issue” (Erviti et al., 2018, p. 46). The authors point to the strong influence of special interest groups but assert that other psychological, social, and cultural factors must also be taken into account for a better understanding of climate change in online videos. Erviti et al. have also found that the uploaded user generated content about climate change in their sample in general is more controversial and in their eyes of dubious veracity than videos coming from professional media organizations or scientific institutions.

Concerning online videos about climate change another question is if content specifically created for online video platforms reaches more or as much audiences as those that had been produced for TV and then been posted on the web. De Lara et al. (2017) have studied a sample of online videos on climate change retrieved from the Google video search engine in order to answer this question. The authors found that videos on climate change that have been created especially for online environments

⁵<https://www.youtube.com/user/1veritasium>

⁶<https://www.youtube.com/user/Vsauce>

⁷<https://www.youtube.com/user/scishow>

attracted more viewers and led to more public engagement than videos produced specifically for TV stations. They conclude that “the capacity of online videos on climate change to generate visits and foster audience participation is greater when the online video has been specifically designed to be transmitted on the Internet, rather than when it has been produced to be broadcast on television and is later published on the internet. Nevertheless, we have also observed that the full potential of the online video format is not harnessed, as the majority of such videos do not include elements that foster user interaction and that might thus increase dissemination” (De Lara et al., 2017, p. 18). As a result, it seems that public communication of climate change could profit enormously from the creation of scientifically accurate videos that have been created specifically for online video platforms with interactive elements that engage various audiences.

However, it is not very clear how various audiences do prefer to engage interactively with video content and what the outcomes of such interactions are. Shapiro and Park (2015), for instance, have focused their research on a specific element of aforementioned user interaction: They have selected a sample of YouTube videos focusing on climate change and have conducted a semantic analysis of comments on the video. They found that the comments did not necessarily address the issues raised in the YouTube videos. However, the majority of comments were science-focused: “The results indicate that, regardless of the narrative, science-based comments dominated, but often discussed climate change in general instead of specific videos to which they were attached. In the absence of gatekeepers, YouTube users rode the coattails of popular videos about climate change, and added the videos’ messages by highlighting evidence of weak, strong, or politicized science” (Shapiro and Park, 2015, p. 115). These results suggest that many viewers use the opportunity to add their feedback to the videos. However, in many cases the comment section is not necessarily used as intended but also used to point viewers to alternative (non-scientific) sources and views and discuss more general issues and not the actual content of the video. Research on commenting behavior in different online contexts has found that particular ways of commenting can indeed alter the interpretation of the actual online content by various users (e.g., Anderson et al., 2013).

Not only the comment sections, which are often but not always open for the points of views of the viewers, but also non-content specific meta information such as the number of views could technically be used to influence the perception of the content. Spartz et al. (2017) have conducted an online experiment in order to explore the role of contextual information embedded in YouTube as normative social cues to users. They have taken a YouTube video about climate change and experimentally examined whether the number of views listed under the video had an influence on the viewers’ thoughts about how others feel about climate change and perceptions of issue salience. They found that the meta-information such as the number of views displayed on YouTube indeed had an influence: “Participants in this experiment were exposed to a YouTube video about climate change using two experimental conditions, one providing a small number of views under the video and the second listing

a large number of views. Results suggest that the “number of views” cue did, indeed, influence participant perceptions of the importance assigned by other Americans to the issue of climate change. Further, compared to low self-monitoring participants, high self-monitoring participants registered an increase in their own judgment of issue importance” (Spartz et al., 2017, p. 1).

Unfortunately, very little is known so far about how various social groups use YouTube as a tool for recruiting and engaging audiences for issues such as climate activism. Askanius and Uldam (2011) provide a rare exception and have studied how the radical activist network “Never trust a Cop” (NTAC) used YouTube for climate change activism and for mobilizing protest against the 15th UN Climate Conference, COP 15, in Copenhagen. Through interviews with activists the authors found out that from the point of view of the activists YouTube is an ambiguous space for contesting dominant social discourses. On the one hand it is embedded in a hostile and market-driven capitalist media environment, that they see also partly responsible for what they are protesting against. On the other hand, the use of YouTube is necessary for reaching and mobilizing new audiences that they could not reach by the use of their own alternative activist networks alone. Consequently, YouTube videos have also been embedded in many alternative media platforms. In this sense the use of YouTube serves a dual purpose: to reach new audiences and the mass media (for instance by posting spectacular videos calling for violent riots), but also as a mobilization call for their established members and followers. Clearly, more research is needed on how various social groups use online video platforms such as YouTube for engaging audiences and the dissemination of content on climate change and other science and environmental communications.

These publications show that so far only a small set of particular issues in relation to climate change on YouTube has been studied empirically. The research so far infers that online videos provide an important channel for the public communication of climate change, but also that further research is needed to get a better understanding on climate topics in online videos and their impacts on various audiences. It is fair to say that there are still big gaps in the research literature. For instance, so far no research is available on how topics such as climate engineering or geoengineering are represented in online video platforms such as YouTube.

Another important aspect of environmental and science communication on YouTube is pointed out by Jaspal et al. (2014). They have examined the representation of Fracking (extraction of shale gas through hydraulic fracturing) on YouTube. This method of geological resource extraction is highly controversial for its environmental and economic cost and benefits and other side-effects. Jaspal et al. (2014) have analyzed the fifty most viewed YouTube videos about “fracking shale gas” using qualitative thematic analysis. The results showed that the analyzed YouTube videos did not only discuss environmental and economic costs and benefits, but also social and psychological impacts on individuals and communities. The authors note that these impacts of fracking on those involved in it or those living in the vicinity of fracking sites so far had hardly been noticed or even studied. The value of studying YouTube

videos therefore was to make these voices heard and to provide first-hand insight into the social and psychological dimensions of fracking and give social researchers fine-grained qualitative data on how this new resource-extraction technology led to various forms of identity threats. Following this line of research, it would be interesting to find out if there are also YouTube videos that represent the views of those that are already heavily affected by climate change.

In this context, it is very important to understand that YouTube is not only a valuable “cultural archive” of online video content but also a growing social online community in which some users subscribe to the channels of other users and react in the form of video responses, and others use textual comments or like, recommend, and share contents and so on (Burgess and Green, 2009). Snickars and Vonderau (2009) describe YouTube as a platform, an archive, a library, a laboratory, a database and a medium at the same time. Kavoori (2011, p. 3) therefore suggests “to see YouTube as much more than a website—it is a key element in the way we think about our on-line experience and (shared) digital culture.” Hartley (2012) describes the internet as a mixture of “probability archives,” with YouTube being the prime example. This means that one cannot know what content one will find once one starts searching there and that the content of YouTube is evolving and dynamic, but not reliable:

“YouTube is an unreliable archive. You never know what you’ll find or not find, and the archive changes constantly. A probability archive is random, complex, uncertain, indeterminate, and evolving as to its contents at any given moment. But it contains much more information than a regular archive can manage.” (Hartley, 2012, p. 167).

In the context of this contribution the main question is what kind of information users will find when they are looking for climate change and climate engineering on YouTube. Following Hartley (2012) it is uncertain what kind of content is stored on YouTube, and how the quality of the information is. Even when one is looking for scientific terms and issues, it might still be the case that the resulting videos that come up as search results are parodies, mashup, remix and music videos, advertisements, PR material and commercials, but they can also be academic lectures and reports and clips from mainstream TV stations and products of professional science and environmental correspondents. All content on YouTube has equal weight since no one is curating the video archive (see also: Gehl, 2009).

For these reasons the video-sharing site YouTube has become almost an epitome of participatory culture (Burgess and Green, 2009). However, this fact is not without problems. For instance, when an unknown disease is breaking out, rather little scientifically verified information is available at first and YouTube (together with various other social media sites) becomes a prime channel for spreading misinformation and harmful rumors (Basch et al., 2015). Another reason for the spread of problematic and potentially harmful content is that video formats have become extremely popular and rapid technological advances and mobile technologies allow more and more people not just to watch videos, but also to produce and upload them themselves. From the point of view of the scientific community there is an obvious downside. Actors that deny

climate change or promulgate conspiracy theories about climate engineering can easily use online videos to spread their views quickly and globally.

In this contribution YouTube is understood as a boundary object (Star and Griesemer, 1989; Bowker and Star, 1999). Boundary objects bring various social worlds or “communities of practice” together and they are necessary to negotiate areas of overlap between multiple social worlds. It has already been mentioned that YouTube is more than just a social media site, it has various qualities and meanings for different people and it is used for various purposes by a very diverse set of users. A boundary object is any object that is part of multiple social worlds and that facilitates communication between them; it has different identities in the various social worlds that it inhabits (Star and Griesemer, 1989). Therefore, boundary objects must be simultaneously concrete and abstract, fluid, and well-defined, or in the words of Star and Griesemer:

“Boundary objects are objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites” (Star and Griesemer, 1989, p. 393).

In their seminal paper on boundary objects Star and Griesemer (1989) explicitly mention repositories as one type of boundary objects. I will revisit the boundary object concept after explicating the search terms used and the methodological approach of this study and presenting the main results of this study.

INVESTIGATING CLIMATE, CLIMATE CHANGE AND CLIMATE ENGINEERING ON YOUTUBE

Social scientists, (social) media and (science) communication researchers have just begun to study YouTube and other online video-sharing websites empirically, and there is still a gap in the research literature on what kind of contents users find there, how they find it there, who uploads content with what kinds of intentions and how different groups of users perceive and make sense of the content they find on online video-sharing websites, such as YouTube. The aim of this research is to find out more about what kind of information concerning climate change and climate engineering users find on YouTube. Here it is of special interest if the information found on YouTube corresponds with mainstream scientific positions or if it challenges scientific views. Ten search terms were used to find videos on YouTube. These were:

1. Climate
2. Climate Change
3. Climate Engineering
4. Climate Manipulation
5. Climate Modification
6. Climate Science
7. Geoengineering
8. Global Warming
9. Chemtrails
10. Climate Hacking

The ninth and tenth search terms are terms that are often used by opponents of mainstream science, particularly in online environments⁸. They have been included in the sample as control terms to find out whether these searches lead to different results than the previous terms and whether these results then support or challenge mainstream scientific views.

The search terms relating to climate and climate modification topics were selected because climate topics are currently of particular social relevance and have been broadly discussed in public, politics, and the media (e.g., De Lara et al., 2017). Painter et al. (2016) have argued that it is of particular importance to understand how digital media cover climate and climate change topics, because they are very influential, but also because specialist correspondents on science and the environment have been reduced in many of the traditional journalistic media organizations.

Various studies found that in the expert community of scientists that are studying climate change professionally there is a scientific consensus on anthropogenic global warming and global climate change⁹. For instance, a survey of over 12,000 peer-reviewed climate science papers by Cook et al. (2016) has found a 97% consensus in the peer-reviewed literature that humans are causing global warming. From a scientific point of view, it is a fact that climate change is happening and that it is caused by human beings (e.g., National Academy of Science, 2010).

A technical approach that is discussed in scientific and engineering expert communities is to apply climate engineering or geoengineering to deal with or mitigate the consequences of anthropogenic climate change with technical means. The Royal Society (2009, p. 77), for instance, defines geoengineering as: “The deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change.” The terms climate engineering and geoengineering are often used interchangeably and involve technologies, such as carbon dioxide removal techniques, solar radiation management techniques, and others such as massive forestation to absorb greenhouse gases such as Carbon dioxide (CO₂) (Royal Society, 2009). Both the terms climate engineering and geoengineering stem from scientists and scientific discussions about how to deal with or mitigate the consequences of anthropogenic climate change with technical means. Compared to other scientific fields it is a rather young epistemic community that considers using technoscientific means, among others, for dealing with the consequences of climate change (e.g., Matzner and Barben, 2018). However, climate and geoengineering are seen as very risky technologies that are also controversially discussed within the scientific community (Stilgoe, 2015).

In some media reports and especially on the Internet climate engineering and geoengineering sometimes appear together

with another term: “chemtrails”. For instance, in Germany it was reported that Member of Parliament Martin Bäumer posed a question to the German Parliament in December 2016 about geoengineering and the harm that “chemtrails” cause (Fisser, 2016). In Austria, Norbert Hofer, right-wing presidential candidate in the year 2016, has also initiated various parliamentary inquiries about “chemtrails” and the dangers that he thinks they are posing to the citizens (e.g., Hofer, 2007). The term “chemtrails” is derived from the condensation trails of airplanes in the sky (contrails). Some call them “chemtrails” because they think they have been purposefully enriched with toxins, microchips or other harmful substances and consider them as evidence for clandestine government, military, industry, or other research operations (e.g., Hepfer, 2016). “Chemtrail” conspiracy theorists often also deny the IPCC view on anthropogenic climate change for various reasons. In their view it is a made up reason for applying secret harmful atmospheric spraying programs. Cairns (2016) studied the “chemtrail” activist movement and describes its worldview as that of a world conspiracy theory that includes the belief in a powerful, evil, and clandestine group that aspires to global hegemony, a position that is clearly located beyond scientific mainstream positions.

Shearer et al. (2016) have investigated the “chemtrail” conspiracy issue empirically. They surveyed two groups of experts: atmospheric chemists with expertise in condensation trails and geochemists working on atmospheric deposition of dust and pollution to evaluate the claims of people who believe in a secret large-scale atmospheric program. The results of the survey show that 76 of the 77 scientists (98.7%) that took part in this study said they had not encountered evidence of a secret large-scale atmospheric program. From a scientific point of view, it is fair to say that the “chemtrails” discourses are mere conspiracy theories and have no relation to geoengineering, climate engineering, climate science or climate change as they are discussed within the scientific and engineering communities. Tingley and Wagner (2017, p. 5) assert: “Chemtrails are not real. Belief in the chemtrails conspiracy is. Between ~30 and 40% of the general US public appear to subscribe to versions of the conspiracy theory, numbers only topped by the large fraction (~60%) of social media discourse, more on Twitter, focused on the topic.” The term “chemtrails” was also included in the sample because it appeared in the media and particularly often in the Internet and in social media discussions referring to climate and geoengineering. YouTube as a social media site is also known as a popular platform for political and many other “marginal” forms of activism (e.g., Uldam and Askanius, 2013).

Studying audio-visual content on YouTube empirically is still challenging. There are many elements that could be studied, for instance the genre of videos, the user statistics, the algorithmic recommender system of YouTube, or the comments from other users, among others (Kavoori, 2011). In (health) communication research it has become a convention to take, for instance, 100 videos that have received the highest number of views and that appear after entering a particular search term or search string. Then these videos are analyzed for their medical accuracy (e.g., Basch et al., 2015). This approach, however, is not going to

⁸See for instance:

<http://contrailscience.com/a-brief-history-of-chemtrails/>
<https://www.skepticalscience.com/Climategate-CRU-emails-hacked.htm>
<https://slate.com/technology/2015/02/nrc-geoengineering-report-climate-hacking-is-dangerous-and-barking-mad.html>

⁹See also the more detailed summaries of research on the scientific consensus on global climate change at: <https://www.skepticalscience.com/global-warming-scientific-consensus-advanced.htm>

provide answers to the question what people will find, if they use YouTube as a search engine. It will only answer the question what the quality and medical accuracy of videos are that have been viewed most often, no matter how users found them.

Another problem, that often builds up on the question of content is the questions of searching (many users use YouTube also as a search engine): the over-reliance on particular search engines (e.g., Google) and the increasing personalization of internet searches may not only help finding the information and content one is looking for, but by privileging some results over others they are actually also hiding other results and making it much more difficult to find particular contents. This problem is exacerbated by the personalization and individualization of searches, which results in more of the same kind of content being shown to users (e.g., the so-called “filter bubble” or “echo chamber”) and often the search results are not transparent at all (e.g., Pariser, 2011). This means that two users who are using the same search term on the same platform might get different search results. The methodological consequence is that sampling online content via search engines is problematic, since personalized searches and the “filter bubble” (Pariser, 2011) or “echo chamber” problem will most likely distort the results and lead to various biases (Emmer and Strippl, 2015).

An innovative methodological approach presented in this contribution is to use the online anonymity network Tor¹⁰ in order to alleviate potential biases that are results of personalized internet searches. The free software and open network Tor directs Internet traffic through a free, worldwide, volunteer network of thousands of relays. Location, destination and IP address are encrypted multiple times in this process through randomly selected Tor relays and only the final relay decrypts the innermost layer of encryption and sends the original data to its destination without revealing the source IP address (e.g., Nicol, 2016). In the research presented the Tor software has been installed and used to search for 10 keywords on YouTube relating to climate science, climate change, and climate manipulation (with cookies being deleted and cache being cleared). Each search has been repeated at least three times using default search settings in English without restrictions, each time with a new identity provided by the Tor anonymity network. This procedure has been applied in order to obtain a randomized sample and to circumvent the filter bubble problem.

All search results have been recorded. If more than 80% of the results in the third search were the same as in the first and second search (which was the case in all searches conducted), the results of the third search on YouTube for a particular search term were taken as basis for the analysis of the first 20 videos that YouTube provided on the result page (that is typically all results from YouTube’s first result page, see also: Rieder et al., 2018). This research strategy was adopted in order to have an approximation on what an average (Tor) internet user finds if she or he searches for a particular term on YouTube. The first 20 results encompass all the results that a YouTube search provides for a particular search term on its first result page. These 20 videos have been selected and analyzed individually because these are the videos

that are most likely to be noticed by the users if they are searching for information on YouTube.

The sample of this study consists of 200 videos, 20 videos for each search term. The searches have been carried out incrementally between January 31, 2015 and December 15, 2015. Two search terms have been added later on (“climate manipulation” on April 29, 2016 and “climate modification” on December 5, 2018) in order to enlarge the size of the sample. All textual and numerical information that YouTube provides for each video (such as the number of views) has been captured and archived. In order to study climate, climate change, and climate engineering on YouTube, this study selected 200 YouTube videos and analyzed them using qualitative thematic analysis. A heuristic classification tool has been applied for further categorization. Four categories have been created to classify the YouTube videos:

1. Videos supporting mainstream science and the scientific consensus view on human induced climate change¹¹ (Category 1)
2. Discussion and debate formats in which mainstream science is discussed with opponents and no particular position is advocated in the video (“journalistic balance”) (Category 2)
3. Videos propagating denial of scientific mainstream positions, such as denial of human-induced climate change (Category 3)
4. Conspiracy theories about science and technology without reference to actual scientific discussions (Category 4)

The videos have been watched one by one. Duplicate videos (videos that appeared in previous searches using other search terms) were omitted and another video further down the search results was selected instead, so that no video was analyzed more than once in the sample. Irrelevant videos (such as advertisement clips for heat pumps found using the search term “climate modification”) were also omitted and another video further down the list of search results was selected instead.

The main focus on the analysis of the selected videos was on whether or not they adhere or challenge the scientific consensus on climate change. The results of the IPCC reports from 2013 onwards have been regarded as the scientific consensus view, with the main conclusion that humans are the “dominant cause” of global warming since the 1950s¹². While watching the videos memos were taken about all statements that relate to climate change in the video. In this sense “memoing” was employed as a procedural and analytical strategy (Birks et al., 2008). If the majority of these statements adhered to the IPCC position the video was classified in category 1 (also when the content was about climate/geoengineering). If the adhering and contradicting statements about climate change (or climate/geoengineering) were balanced the video was placed in category 2. If the majority of the statements on the memos was related to climate change and

¹¹The reports of the IPCC form the basis for the scientific consensus view on made-made climate change. For a list of their assessment reports see: <https://www.ipcc.ch/reports/>

¹²See for instance: Working Group I contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) Climate Change 2013: The Physical Science Basis. Online: <https://www.ipcc.ch/report/ar5/wg1/>

¹⁰TOR: The Onion Router, <https://www.torproject.org>

contradicted the IPCC position the video was placed in category 3. If the statements in the videos were related to issues of climate or climate change or climate/geoengineering but advocating a position that endorsed the “chemtrails” theory (or similar conspiracy theories about secret climate/weather manipulations) then the video was placed in category 4.

After the videos have been categorized it was calculated how many views the different categories of videos have received and what kind of videos were viewed most often. On YouTube counting views is a way of evaluating success. Van Es (2019) argues that the number of views videos on YouTube receive is the pervasive category enacted through the platform. The last step of the analysis examined if evidence for strategically distorted communications as reported by Erviti et al. (2018) could be found in the sample of YouTube videos. This step involved also the meta information provided with the individual videos, such as the descriptions and tags of the video, or the comment sections.

RESULTS

The sample contains 200 videos that have been analyzed and classified in four different categories. The oldest video in the sample was uploaded on September 22, 2008. The most recent video included in the sample was uploaded on October 18, 2018. The shortest video in the sample is only 37 s long, while the longest video is 2 h, 4 min, and 27 s. Ninety of the 200 videos in the sample are <10 min long.

The videos included in the sample encompassed different types of styles and genres, but most of them are either snippets or excerpts from previously broadcast professional TV programs (see also: De Lara et al., 2017) or self-made amateur videos. A few of the videos in the sample are also public talks and academic presentations. **Table 1** shows the distribution of the videos along the four categories that were created to categorize the videos corresponding to their stance toward mainstream scientific positions.

For the search terms *Climate*, *Climate Change*, *Climate Science*, and *Global Warming*, the absolute majority of videos in the sample adhere to the scientific consensus view. Most of them are parts of TV news programs or professional TV documentaries that in general accurately explain climate change and global warming, and often also underline the serious negative consequences of man-made climate change for people, animals, and plants. Many of the clips of these four search terms also feature quotes or comments from eminent climate scientists and researchers. A few of these video clips are TED talks¹³, or internet videos from scientific institutions, such as the Royal Society. Only some of the videos for these four search terms (9 out of 80 videos) challenged mainstream scientific positions, and even fewer videos (2 of 80 videos) are discussion formats in which climate scientists discuss climate change with climate change deniers.

The picture changes entirely if we focus on the videos that appear as results in the searches for *Geoengineering*, *Climate*

Manipulation, *Climate Hacking*, *Climate Engineering*, *Climate Modification*, and *Chemtrails*. Here the majority of the videos (97 of 120 videos) oppose scientific consensus views or promulgate straightforward non-scientific conspiracy theories. Very few of the videos in this case explain the scientific rationale and engineering ideas behind possible attempts to manipulate or “engineer” the climate as a reaction to global climate change. However, there is one TED talk and a few academic contributions from various universities and research institutes, and one interview with a scientist from a BBC TV program that try to do so. In the case of these search terms one mostly finds self-made and amateur videos of protagonists who believe in the so-called “chemtrail” conspiracy theory, which claims that sinister and evil forces spray the population with toxic substances from airplanes for various reasons, but also a range of videos from people who deny man-made climate change for various reasons. In the “chemtrail” case the same protagonists appear over and over again in many of the videos. For instance, “chemtrail” conspiracy activist Dane Wigington¹⁴ uploaded 10 of the 120 videos on his own YouTube channel and is mentioned in the titles of five more videos, and appearing and quoted in various other videos. Many of the titles, descriptions and comments of the “chemtrail” conspiracy videos call on the viewers to share and distribute the videos widely and to do their part to raise public awareness of the worldwide “chemtrail” conspiracy.

The results for the search terms *Geoengineering* and *Climate Modification* are particularly striking in this context: in this case 92.5 percent of the search results adhere to the “chemtrail” conspiracy theory. The search term *Climate Hacking* addresses various issues; it is a non-scientific term for climate manipulations but also refers to hacked emails from climate scientists, that climate change deniers (unsuccessfully) used as evidence against human-induced climate change (Holliman, 2011). Most of the videos that appear as results in this case are clearly challenging mainstream scientific positions. Another interesting result is that 95 percent of the videos that came up as results for the search term *Chemtrails* were from users that believe in the “chemtrail” conspiracy and there is only one video in the sample that attempts to challenge the conspiracy theory about “chemtrails” in any way.

The number of views that a video received on YouTube is displayed along the video. YouTube counts a view after a user has watched a video for at least 30 s (see also: Van Es, 2019)¹⁵. In total, the videos supporting the scientific consensus view had slightly more views¹⁶ (16,941,949 views) than those either denying climate change (685,068 views)

¹⁴Dane Wigington is connected to the website <http://www.geoengineeringwatch.org> and runs an own YouTube channel with more than 86,700 subscribers [December 30, 2018]: <https://www.youtube.com/user/danewigington/>. This YouTube channel is connected to three more YouTube channels named: Geoengineering Watch, GeoengineeringWatch.org, Geo Watch.

¹⁵See for instance: <http://marketingland.com/whats-a-video-view-on-facebook-only-3-seconds-vs-30-at-youtube-128311>

¹⁶It must be mentioned here that there is the possibility that the numbers of views YouTube videos are said to receive could be manipulated. See for instance: <https://www.nytimes.com/interactive/2018/08/11/technology/youtube-fake-view-sellers.html>

¹³Self-description on their website: TED (Technology, Entertainment, Design) Talks are influential videos from expert speakers on education, business... See: <https://www.ted.com/talks>

TABLE 1 | Distribution of YouTube videos in the sample ($n = 200$).

Search term	Scientific consensus view	Debate format (balanced)	Climate change denial	Chemtrail conspiracy	Sum
Chemtrails	1 (5%)			19 (95%)	20 (100%)
No of views:	82,352 views (1.5%)			5,410,057 views (98.5%)	5,492,409 views (100%)
Climate	18 (90%)		1 (5%)	1 (5%)	20 (100%)
No of views:	1,255,805 views (95.7%)		25,076 views (1.9%)	31,915 views (2.4%)	1,312,796 views (100%)
Climate Change	18 (90%)	1 (5%)	1 (5%)		20 (100%)
No of views:	6,419,912 views (95.4%)	284,533 views (4.2%)	22,991 views (0.3%)		6,727,436 views (100%)
Climate Engineering	9 (45%)			11 (55%)	20 (100%)
No of views:	17,127 views (5.4%)			300,269 views (94.6%)	317,396 views (10%)
Climate Hacking	6 (30%)	1 (5%)	5 (25%)	8 (40%)	20 (100%)
No of views:	85,836 views (13.7%)	160 views (0.02%)	153,607 views (24.5%)	386,563 views (61.7%)	626,166 views (100%)
Climate Manipulation	2 (10%)	1 (5%)	2 (10%)	15 (75%)	20 (100%)
No of views:	1,801 views (0.7%)	78,452 views (31.04%)	252 views (0.1%)	172,228 views (68.15%)	252,733 views (100%)
Climate Modification:	1 (5%)			19 (95%)	20 (100%)
No of views:	1,904 views (0.02%)			8,448,635 views (99.98%)	8,450,539 views (100%)
Climate Science	16 (80%)	1 (5%)	3 (15%)		20 (100%)
No of views:	2,592,520 views (93.5%)	51,251 views (1.8%)	129,432 views (4.7%)		2,773,203 views (100%)
Geoengineering	2 (10%)			18 (90%)	20 (100%)
No of views:	29,752 views (1.9%)			1,504,920 views (98.1%)	1,534,672 views (100%)
Global Warming	16 (80%)		4 (20%)		20 (100%)
No of views:	6,454,940 views (94.8%)		353,710 views (5.2%)		6,808,650 views (100%)
Sum	89 (44.5%)	4 (2%)	16 (8%)	91 (45.5%)	200 (100%)
No of views:	16,941,949 views (49.4%)	414,396 views (1.2%)	685,068 views (2%)	16,254,587 views (47.4%)	34,296,000 views (100%)

or supporting the conspiracy theory about “chemtrails” (16,254,587 views)¹⁷. However, taken together the videos opposing the mainstream scientific position received 16,939,655 views, only 2,294 views less than the videos which are following the scientific consensus view. The videos found using the search terms *Chemtrails* (5,410,057 views) and *Climate Modification* (8,448,635 views) had the most views among the videos that are opposing the scientific mainstream view.

There are 48 videos in the sample that had more than 100,000 views (see **Table 2**). Most of these were “chemtrails” conspiracy videos (20 videos). Parts of programs or whole programs taken from professional media organizations, such as footage from public or commercial TV stations came second (15 videos). Clips from Science YouTubers such as *Veritasium* or *SciShow* (four videos) were third in numbers for views; furthermore, there were professional learning videos (two videos); videos from scientific institutions (*The International Geosphere-Biosphere Program* and *The Intergovernmental Panel on Climate Change IPCC*) (two videos); climate change denial videos (two videos); and one amateur music video, one TED talk video; and one amateur documentary video.

Various “chemtrail” conspiracy videos have had more than 100,000 views. Among them are for instance the video “CIA Whistleblower Speaks Out About Climate Engineering...” uploaded by Dane Wigington on October 10, 2016 which was found using the search term *Climate Modification*. The video is the recording of a presentation by Kevin Shipp, introduced as a former CIA officer, in which he is publicly speaking out on what he thinks is the “shadow government” of the United States which is conducting secret weather modification programs and experiments. Another “chemtrail” conspiracy video is titled “What in the World are they spraying?” uploaded by Justin Wallis on December 10, 2010. It was found using the search term *Chemtrails*. This video is made in the genre of a documentary that uses investigative journalism to expose what the makers understand as the “truth” about the “chemtrail” conspiracy.

Videos from professional media organizations are for instance from the US HBO TV program *Last Week Tonight with John Oliver* and titled “Climate Change Debate.” It was found using the search term *Climate*. This humorous video endorses the scientific mainstream position and uses real people in a sketch to show what the percentage of climate scientists is that supports the view that humans cause climate change. Another video from a professional media outlet is from National Geographic. It is titled “Global Warming 101” and was found using the search term *Global Warming*. A documentary video by Discovery Channel titled “Global Warming, What you need to know, with Tom Brokaw” was found using the search term *Global*

¹⁷A Google Trends (www.google.com/trends) analysis of the interest in *YouTube* search terms during the sample period revealed that the search terms *Climate*, *Climate Change*, *Global Warming* were most popular during the sample period, followed by the search terms *Chemtrails* and *Climate Science*.

TABLE 2 | YouTube videos in the sample with more than 100,000 views/1,000,000 views.

YouTube videos in the sample with more than 100,000 views	
Chemtrail Conspiracy Videos	20 videos
Professional Media Content (mainly from TV stations)	15 videos
Science YouTubers	4 videos
Scientific Institutions	2 videos
Professional Learning Videos	2 videos
Climate Change Denial Videos	2 videos
Amateur Music Videos	1 video
TED talk	1 video
Amateur Documentary Videos	1 video
Sum	48 videos
YouTube videos in the sample with more than 1,000,000 views	
Chemtrail Conspiracy Videos	3 videos
Professional Media Content (mainly from TV stations)	3 videos
YouTubers	1 video
Sum	7 videos

Warming. The most watched video from science YouTubers was a video from *Veritasium* titled “13 Misconceptions about Global Warming,” that was found using the search term *Global Warming*. This video debunks misconceptions about global warming and explains the scientific findings concerning global warming. The most watched video from a scientific institution was “Climate Change: The State of the Science” by the *International Geosphere-Biosphere Program*, which was found using the search term *Climate Science*. The second most watched video from a scientific institution was called “English—Climate Change 2013: The Physical Science Basis” by the *Intergovernmental Panel on Climate Change (IPCC)*, which was also found using the search term *Climate Science*. Both videos explain and review the evidence and data that speak for anthropogenic climate change.

However, only seven videos had more than 1,000,000 views in the sample. These were videos from professional TV stations (Last Week Tonight with John Oliver on HBO [4,9 million views]; the National Geographic climate clip [2,3 million views], and the documentary on the Discovery Channel [1,1 million views]). The video by the Science YouTuber *Veritasium* (“13 misconceptions about climate change”) had 1,7 million views. A conspiracy video titled “Something unseen is happening worldwide (2017–2018)” uploaded by the user *THAT IS IMPOSSIBLE* on August 28, 2017 had staggering 5,3 million views, it is the video with most views in the sample. This video shows quite spectacular amateur footage of extreme weather events and of a solar eclipse and also various climate maps of the earth. Some added graphics and an unseen narrator suggest that some sort of sinister climate manipulation is going on that “they” want to keep a secret. The pseudo-documentary “What in the World are they spraying?” had 1,6 million views and the CIA whistleblower video uploaded by “chemtrails” activist Dane Wigington had 1,4 million views.

DISCUSSION

YouTube is an important information source for many people when they want to find information about science and research (e.g., Medienpädagogischer Forschungsverbund Südwest, 2015; Forum Wissenschaftskommunikation, 2016). The research presented is particularly interested in the question what contents user find when they are searching for climate and climate modification topics on YouTube. The results of this exploratory research show that in the case of climate change, climate science and climate manipulation rather general search terms such as *Climate*, *Climate Change*, or *Climate Science* are most likely to bring up videos as results that confront the users in their majority with mainstream scientific positions on human-induced climate change. The videos in this case are mainly videos or parts of videos from professional media organizations such as news programs and science documentaries. Here it is worth noting that almost all of the contents from professional media organizations in the sample endorse the mainstream scientific position on anthropogenic climate change (see also Erviti et al., 2018). There are four more videos that come in debate or discussion formats in which climate experts meet climate change deniers. None of the videos in the sample from professional media organizations endorses or supports conspiracy theories such as the one around “chemtrails.”

From a scientific point of view the quality of information of the videos in the sample from professional media organizations is higher than that of most of the user generated content found on YouTube (see also Erviti et al., 2018). However, there are various noteworthy exceptions: for instance, the video clips from Science YouTubers such as *Veritasium* or the *SciShow* are also of high scientific quality, and the quality of information in the science learning clips or videos of scientific institutions, but also in recorded academic lectures and talks is also high. These results indicate that YouTube could indeed be a very valuable tool for public science and environmental communication and for informing citizens about climate change and other science and research-based issues.

However, more specific search terms, such as *Climate Engineering*, *Climate Modification*, *Geoengineering*, or terms such as *Climate Hacking* or *Chemtrails* largely led to videos that confront the users with positions that challenge mainstream scientific positions on climate change, or to outspoken conspiracy theories about so-called “chemtrails”—an issue which poses a major challenge to climate change communication and the public communication of science, research and technology in general. The latter is particularly the case if users search for “Geoengineering” on YouTube. The “chemtrail” conspiracy theorists very successfully “occupied” or one could even say “hijacked” this once scientific term and relabeled it, based on their worldview of a global “chemtrails” conspiracy.

In this sense they are using a relatively recent scientific term for making their concern sound more scientific and possibly more reasonable to some people. From their point of view this strategy also has the advantage that “chemtrails” can now jump on the bandwagon when there are actual scientific discussions and events addressing technical options of artificial

climate modification or manipulation. In fact, “chemtrailers” explicitly advise their followers to use the scientific terms, in order not to be immediately identified as conspiracy theorists (Cairns, 2016). On one of the most prominent “chemtrail” conspiracy websites (GeoEngineering Watch, 2015) this strategy is explicitly expressed:

“The geoengineering term is related to hard science, the “chemtrails” term has no such verifiable basis but rather leads anyone that Googles the term straight to “conspiracy theory” and “hoax” definitions. Use the terms “climate engineering” and “geoengineering”.”

This strategy could be identified as an attempt to manufacture internet bias in favor of the worldview of “chemtrail” conspiracy theorists. The purpose is directing internet users to videos and other contents supporting a conspirational worldview and diverting their attention from current scientific discussion about geoengineering or climate engineering, as they do actually take place among members of scientific communities. The usage of similar internet communication strategies and tactics has been applied also by other conspiracy theorists (see König, 2013).

Social media websites and video platforms without editorial control, such as YouTube, provide a very fertile ground for conspiracy theorists and opponents of mainstream science because there are no gatekeepers and hence no quality control is taking place on such channels. This means virtually everybody can upload contents no matter if they are accurate, verifiable, and truthful or not. The rise of social media therefore can raise doubts and also endanger trust in (climate) science, as was shown in recent discussions about fake news (e.g., Weingart and Guenther, 2016). In democratic societies citizens should take part in decision-making processes, also about science and technology because they are constantly affected by them (e.g., Nowotny, 2003). This is especially true for climate and climate engineering politics, that affect the entire planet. However, this principle of democratic decision-making is damaged when citizens cannot inform themselves neutrally about such complex matters, such as for instance climate change or geoengineering, which will most likely become even more important and more controversial topics in the near future, when the impact and consequences of climate change become more severe and directly tangible.

It has been shown previously that groups that oppose mainstream science—such as creationist groups that oppose the theory of evolution for religious reasons—explicitly call their followers to make use of YouTube as an effective tool for “internet evangelism” (Allgaier, 2012). In this context it should also be mentioned that videos from “chemtrailers,” creationists and other opponents of mainstream science are often “mirrored” by their followers; a further strategy for manufacturing internet biases and disseminating content (see also: Fish, 2016). This means that whole videos or parts thereof are also uploaded by various followers and friends, often under various names and with different tags and keywords, so that the same kind of contents appear over and over again in various channels and under various headlines and tags. It is virtually impossible to dam up or delete the content once it has been uploaded and mirrored; the strategy here is to simply “flood” as many social media channels with partisan content

as possible. This practice is another aspect of manufactured internet biases and also applied to distort search results in favor of their own content. Furthermore, “chemtrail” conspiracy activists are using various further social media communication tactics and strategies, for instance they have learnt to use the mechanisms and guidelines for search engine optimization, so that their contents are easily found in internet searches. Another tactic that was found in the videos in the sample was using the comment sections from videos with scientific mainstream views to attack the content and scientific experts and posting links in order to redirect the internet traffic to their own videos.

One striking result of this research is that only one video has been found in the sample that opposed the “chemtrail” conspiracy theory, all other videos about “chemtrails” in the sample supported the conspiracy theory. The conspirational “chemtrail” videos sometimes also very elegantly mimic professional news, documentary and TV discussion formats as they are available from professional media organizations and networks, and they often portray “chemtrail” activists as professionals and experts with scientific and other forms of expertise and credentials. These videos are not from professional media organizations but nonetheless some of the conspiracy videos in the sample are produced along professional standards with high production values. The part of the scientific community that seriously engages with work on climate engineering or geoengineering is so far only very marginally present on YouTube and it seems that the public discourse on the two terms *Climate Engineering* and *Geoengineering* on YouTube is currently dominated by “chemtrail” conspiracy theorists.

In a review article on online communication on climate change Schäfer (2012) noted that climate scientists and scientific institutions do not seem to be major players in online debates about climate change and climate politics. Overall, there are very few videos that try to mediate or initiate discussions between scientific climate change experts and climate change deniers (or conspiracy theorists). On YouTube the views on climate change and climate modification issues are highly polarized (see also: Bessi et al., 2016).

YouTube is indeed a boundary object around which various social worlds and “communities of practice” come together. Cat lovers, make up enthusiasts, gamers, fans of music videos and many other groups of users enjoy interacting with YouTube content. However, YouTube also has a huge potential for public science and environmental communication, but at the same time it also enables conspiracy theorists to hijack issues, tags and search terms, and redirect users to misleading information when they are actually searching for information on science and environmental topics. Others, such as the successful Science YouTubers, might talk about science on YouTube to make a living. On YouTube the scientific community is not necessarily a homogenous community of practice. The scientific consensus view on climate change provided by the IPCC is more or less successfully represented on YouTube. This might also be a result of various political endeavors and a highly professional communication apparatus. The specific subgroup of scientists, however, that is concerned with climate engineering

or geoengineering was not very successful in making their voices heard on YouTube so far.

Minority expertise and scientific reputation does not count on YouTube; every user can talk about almost anything. As an archive used by different communities for entirely different purposes it needs active engagement and adaptation to the rules that YouTube provides. These rules are not transparent, they are changing from time to time and need to be learnt by making use of the boundary object. It is a learning process also in light of how the video platform and the other uses react to one's own behavior. Rieder et al. (2018: 64) assert: "...the video platform arranges search ranking in a way that allows highly active "niche entrepreneurs" to gain exceptional levels of visibility. Feeding on controversy and loyal audiences, these channels consistently appear in top positions, even if their videos most often receive fewer views than more mainstream or conciliatory voices."

From all that could be learnt so far we see that it is necessary that the scientists make use of the YouTube object themselves and don't let themselves be represented by anyone else if they want to stay in charge of the discussions they open up. Overall, it still seems fair to say that YouTube and other online video-sharing websites have an enormous potential as tools for science and environmental education and communication and the professional communities from these subject areas will do well to engage effectively with these communication channels. Various researchers and institutions have recognized that scientific and research institutions should be more proactive when it comes to science and environmental communication via online video formats (e.g., Allgaier, 2016). Haslam et al. (2019) therefore provide a useful set of guidelines for increasing the probability that a video will be found and watched from among the huge number of videos that are uploaded every day. These guidelines could easily be adapted for practical use in science and environmental communication.

The results of this study come with caveats. The research strategy adopted here only allows for a snapshot picture on what is happening on YouTube given the used search terms, based on a rather specific population of YouTube users, at specific points in time¹⁸. It might be the case that users that make use of the Tor anonymity service might have different views on science, research, and conspiracy theories than other parts of the population and also that they use video-sharing sites such as YouTube for different purposes, or interpret YouTube videos differently than other internet users. According to the self-description on the Tor website¹⁹ it is a variety of normal citizens and specialist users that uses the Tor tool for various reasons. In addition, YouTube is a particularly lively website with very heavy internet traffic that is constantly in flux and possible results are likely to change very quickly, also because the company is changing its search algorithms from time to time. This exploratory study tried to shed some light on what kind of information users find when they use YouTube as a search engine for climate related information.

¹⁸A lesson learnt by conducting this research is that in similar research in the future all videos should ideally be sampled on the same day. This would, for instance, make a comparison of the number of views and other metadata more accurate.

¹⁹See: <https://2019.www.torproject.org/about/torusers.html.en>

However, searching on YouTube is not the only way how to encounter YouTube videos: users might as well find them because they are recommended on other social media channels (such as Facebook or Twitter etc.), or because they are embedded in blogs, websites or news reports, or maybe because friends or colleagues have send out links to YouTube videos in emails etcetera. If a YouTube video has many views this does not automatically mean that the majority of users endorse the content of the video. For instance, it might be that some users watch some videos just to amuse themselves and are actually deeply opposed to what they seen in the video.

Also, the research presented here is exploratory in nature and focused on only a few elements of YouTube (video content, number of views). In follow-up research it will be of interest to include further elements for a more complete picture, such as the number of likes, comments (see Shapiro and Park, 2015) self-descriptions, numbers of subscribers to video channels, the YouTube recommender system and various others (e.g., see Spartz et al., 2017).

The results of this research show that there is still an unsolved problem and reason for concern: various individuals and groups that oppose mainstream scientific positions already gained a strong foothold on such channels and seem to have learnt very well how to use them to their advantage. More research on how such groups use YouTube and other social media sites is needed in order to counter them successfully (Leshner, 2012). In addition to research, strategies and actions from scientific and (climate) research organizations and the science communication community are also required for reaching out to citizens via social media and webvideo channels in general, and also for reacting effectively to wrong claims, antiscientific, and conspirational content (e.g., Zollo et al., 2017).

YouTube has been accused persistently from various angles for promoting extreme (political) worldviews²⁰, particularly unsuitable and "disturbing" contents²¹, for promoting conspiracy theories and for systematically distorting the truth²². How exactly YouTube's search algorithms are working is intransparent, but it is known that they are being changed from time to time²³. The business model of YouTube is to provide an internet infrastructure to users so that they can

²⁰For instance: <https://www.nytimes.com/2018/03/10/opinion/sunday/youtube-politics-radical.html>

<https://www.vox.com/policy-and-politics/2018/9/24/17883330/dave-rubin-ben-shapiro-youtube-reactionary-right-peterson>

²¹For instance: <https://medium.com/@jamesbridle/something-is-wrong-on-the-internet-c39c471271d2>

<https://www.buzzfeednews.com/article/charliewarzel/youtube-is-addressing-its-massive-child-exploitation-problem>

²²For instance: <https://www.theguardian.com/science/2019/feb/17/study-blames-youtube-for-rise-in-number-of-flat-earthers>.

<https://www.theguardian.com/technology/2018/feb/02/how-youtubes-algorithm-distorts-truth>.

<https://algotransparency.org/>

²³See for instance: <http://www.replayscience.com/blog/how-does-the-youtube-algorithm-work/>

<http://techtipswithtea.com/youtube-tips/youtube-changes-algorithm-2017-what-it-means-for-you/>

upload content and watch videos, comment on them and so on. YouTube can then sell advertisement space and the data it generates by observing the behavior of its users. From this point of view, it does not matter for YouTube whether users upload or watch conspiracy videos, as long as this brings further traffic to their site. In fact, also some of the conspiracy videos in the sample are being monetized by the users by showing ads or advertising T-Shirts and other items with motives of conspiracy theories.

However, it has been reported that YouTube staff have recognized the problem of spreading misinformation on climate change and conspiracy theories such as the one around “chemtrails” (Hirji, 2018). In July 2018 YouTube started placing short descriptions from *Wikipedia* and *Encyclopedia Britannica* next to videos on topics that propagate conspiracy theories in order to fight misinformation²⁴. So far the effects of countering misinformation this way are unknown and audience and reception research would be desirable in order to find out more about how different parts of the population perceive and make sense of various contents about climate change and climate engineering and other scientific topics on online video platforms such as YouTube.

In addition, still very little is known about what kind of scientific content can be found on YouTube and other online video-sharing websites and also about who it is that is producing

and uploading it (e.g., Erviti and Stengler, 2016). So far it has also been difficult to obtain randomized samples of YouTube and other social media content and one possible solution advocated in this contribution that could easily be transferred to further research is to use the free software and open network Tor for sampling purposes. Further research is also needed on how various other potentially controversial scientific, technological or environmental subjects are depicted on YouTube and other video-sharing websites, ideally in comparison across other social media platforms (see: Tingley and Wagner, 2017, Pearce et al., 2018).

Further research questions must address what kind of actors produce and upload online videos and what the effects and perceptions of these videos are, and also what types of content and videos are especially successful and popular. The academic examination of YouTube and online video-sharing in general has just begun and it is likely that online video traffic is going to grow further in the near future. A solid methodological repertoire to study practices and consequences of online video-sharing empirically is urgently required and empirical and theoretical work needs to draw on various disciplines and interdisciplinary exchange in order to illuminate this interesting and influential social phenomenon.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

²⁴See: <https://youtube.googleblog.com/2018/07/building-better-news-experience-on.html>

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