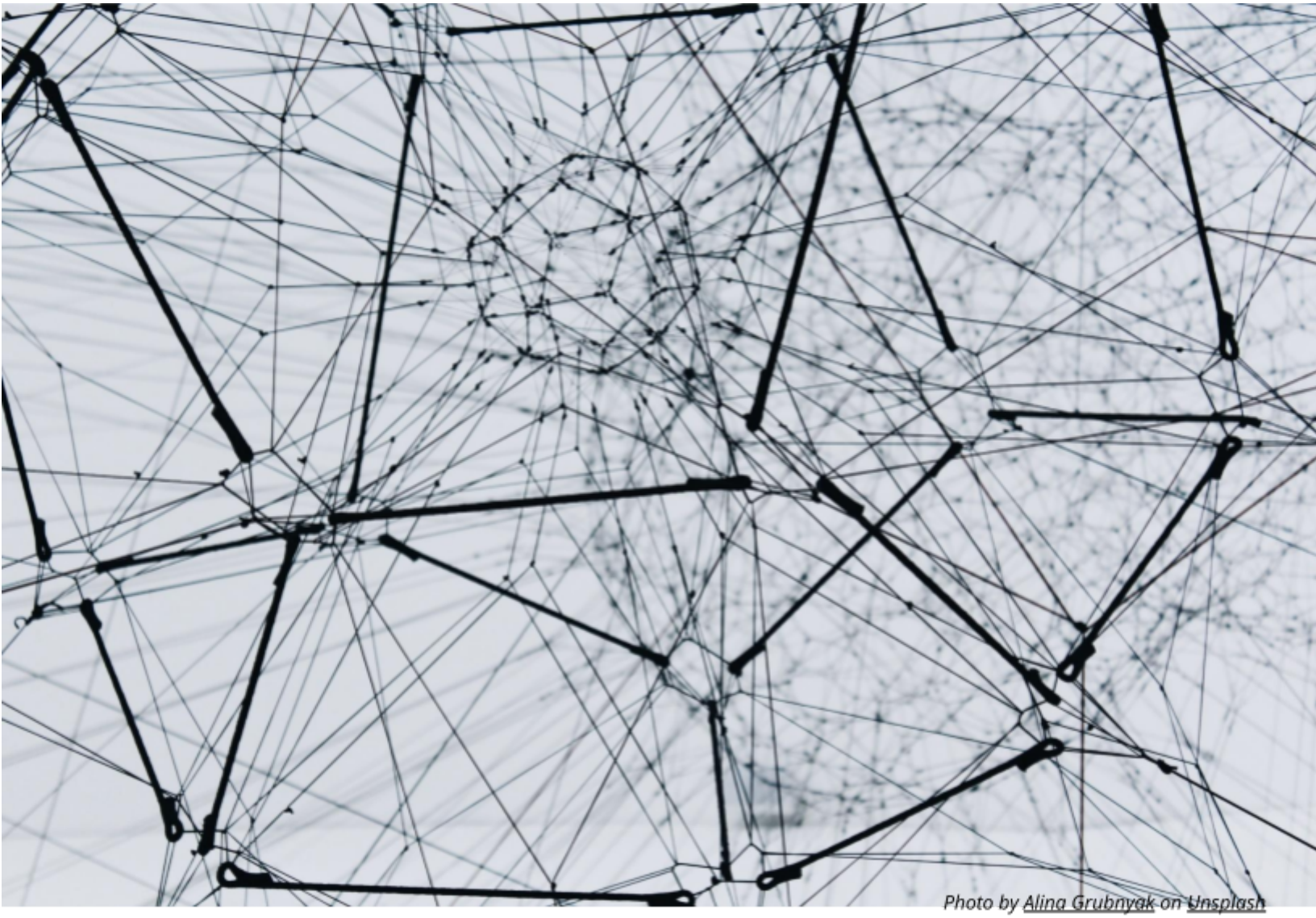

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TRESCA

Trustworthy, Reliable and Engaging Scientific Communication Approaches

D4.2 White paper on best practices for producing science communication videos

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 872855.

PROJECT DESCRIPTION

Acronym:	**TRESCA**
Title:	Trustworthy, Reliable and Engaging Scientific Communication Approaches
Coordinator:	Erasmus University Rotterdam
Reference:	872855
Type:	Research and Innovation Action (HORIZON 2020)
Program:	Science with and for Society (SwafS)
Theme:	(Science) Communication
Start:	01.01.2020
Duration:	28 months
Website:	https://trescaproject.eu
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Consortium: **Erasmus University Rotterdam,** The Netherlands (EUR), Coordinator

Consejo Superior de Investigaciones Científicas, Spain (CSIC)

Observa Science in Society, Italy (OBS)

Zentrum Für Soziale Innovation GMBH, Austria (ZSI)

Science Business Publishing Limited, United Kingdom (SBP)

In a Nutshell, Kurzgesagt GmbH, Germany (KURZ)

DELIVERABLE DESCRIPTION

Number:	**D4.2**
Title:	**White paper on best practices for producing science communication videos**
Lead beneficiary:	**EUR**
Work package:	WP4
Dissemination level:	Public (PU)
Type	Report (R)
Due date:	31-01-2021
Submission date:	29-01-2021
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Acknowledgement: This project has received funding from the European Union's Horizon 2020 Research and Innovation Action under Grant Agreement No 826497.

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Executive summary

Science communication increasingly occurs via digital media. Social media platforms, such as YouTube, have become popular channels among science communicators. Despite this, we know relatively little about how viewers perceive, trust, or judge, this type of science communication. This white paper investigates what drives perceived trustworthiness and reliability in online science communication videos. We present results of video experiments using a well-viewed science communication video on climate change by the animation studio 'Kurzgesagt-In a Nutshell'. Informed by influencing factors suggested by prior research, we manipulated key aspects of the video, such as the gender of the narrator, the narration tone (hopeful vs. pessimistic), and scientific rigor (e.g., provide links to sources, communicate uncertainty). Based on the results, we provide six best practice recommendations for producing effective science communication videos. First, people respond differently to information on climate change depending on their knowledge and climate attitudes. Second, science communicators should avoid using negative statements against someone and shy away from blaming. Third, a video's production value serves as a proxy for overall quality. When the production value was perceived to be high, the video and narrator were perceived more positively too. Fourth, entertainment and signals of trustworthiness should be combined to reinforce the effectiveness of the message. Fifth, communicating uncertainty does not decrease perceived quality. Finally, changes in the narrative need to be clear and explicit to have an effect.

1. Introduction

The need for reliable information is steadily increasing, and the relevance of trustworthy and reliable science communication has become ever more apparent during the ongoing COVID-19 pandemic. Similarly apparent is the tendency of the public to turn away from facts in the face of complex issues. The project 'Trustworthy, Reliable and Engaging Scientific Communication Approaches' (TRESCA) aims to understand and improve science communication by empowering scientists and science communicators to deliver important messages in a way that resonates with the public audience. In this way, we hope to contribute to counteracting misinformation and rebuilding trust in scientific experts and institutions.

The aim of this white paper is to identify best practices for producing science communication videos. We did so by conducting an experiment in which we manipulated specific aspects of an animated science communication video produced by Kurzgesagt - In a Nutshell. Kurzgesagt is a popular German-based YouTube channel which produces videos on a range of scientific topics.

The video we selected for the experiments focused on climate change and responded to climate change skepticism. Climate change skepticism or denial refer to dismissal or unwarranted doubt of the scientific consensus on the rate and extent of global warming, its significance, or its connection to human behavior. Despite the vast majority of scientists agreeing that humans have a (lasting) impact on climate change, there are people in Europe who remain sceptical. According to results of the European Social Value Survey reported in the table below, in most European countries more than 90% think that the world's climate is at least probably changing. Nonetheless, there is a fraction of the population who do not believe in global warming. As a consequence, science communication experts face the critical, yet difficult, task of increasing public understanding, and stimulating engagement within this group of skeptical people.

Table I: Results from the *European Attitudes to Climate Change and Energy*

Country	Climate is probably or definitely changing (%)	Climate has changed at least partially because of human activity (%)	The impact of climate change will have negative effects (%)
Austria	92.5	91.8	74.0
France	96.3	93.8	73.7
Germany	95.4	94.8	77.4
Hungary	91.4	92.7	77.0
Italy	94.8	93.6	69.0
Netherlands	96.2	91.8	61.6
Poland	92.6	89.6	70.4
Spain	95.8	95.7	87.9

Source: European Attitudes to Climate Change and Energy: Topline Results from Round 8 of the European Social Survey. European Social Survey (ESS) Topline Results Series, issue 9, september 2018.

Fit in the overall project

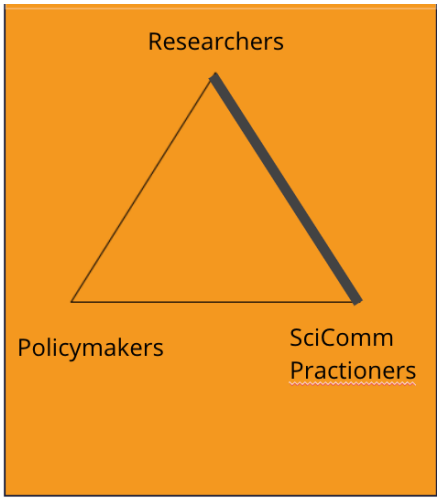
One of the main aims of TRESCA is to create more engagement between different relevant actors in science communication, namely scientific researchers, science communication practitioners and policy makers. These three actors have different strategies to deal with misinformation and to critically engage with the public. In this report we focus explicitly on increasing the mutual learning process between scientific researchers and science communication practitioners. Some scholars claim in fact that there is still a gap between what the science of science communication can offer and the number of communication experts able to grasp these insights and convert them into practice (Gerber et al 2020).

There are various reasons why it is difficult to transform current communication practices. From the point of view of researchers, the incentive structure within academia tends to reward contributions to theory more than contributions to practice. However, the survey about incentives and disincentives for engaging in science communication (D1.5) shows that researchers are intrinsically motivated and willing to communicate their findings to

people in and outside of the scientific community even in the absence of economic or reputational incentives. A majority of researchers see science communication as a moral duty; unfortunately they also say that they lack time and appropriate training to do so effectively. Another problem is that the most common channel for communicating scientific findings are academic outlets. However, scientific articles rarely include practical recommendations relevant to practitioners. Even in those cases where practice recommendations are offered, this information remains inaccessible to media and communication practitioners when scientific articles are hidden behind paywalls.

From the perspective of science communication practitioners and experts, most knowledge originates from practice and daily experience. The problem here is that there is rarely somebody able to collect and organize that practice-based knowledge and able to explain why something works and how to systematically identify both benefits and drawbacks of certain practices. We believe that theory and research can support and complement good practice and know-how. For this reason, this report tries to better understand the mechanisms behind the success of Kurzgesagt's videos by explaining why specific graphical and editorial decisions are especially effective and successful. We try to better connect theories and practices of science communication via this white paper.

Figure I: D4.2 is about enhancing mutual learning between researchers and science communication practitioners



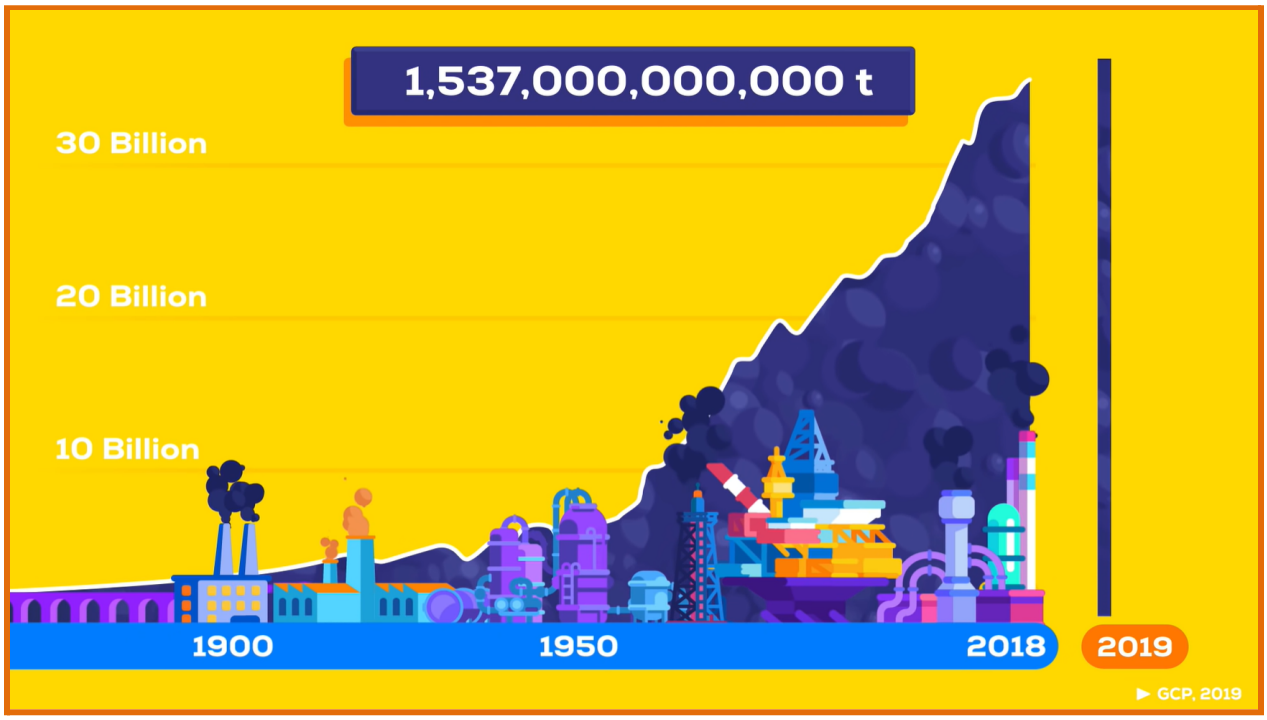
2. Research Design

In this section we explain the procedure followed in task *4.2 Experimental engagement with science communication video variations* in order to test the effects of specific variations in the graphic, sound and narration of the video selected.

The video

Participants watched one chapter of Kurzgesagt's video "Who is responsible for climate change? - Who needs to fix it?". As the title suggests, the video revolves around climate change and which countries should take responsibility in countering this worrying development. The video was published in June 2020 and has been watched over five million times. As explained by Hannah Ritchie on 22 June in an article, the YouTube channel Kurzgesagt teamed up with *Our World in Data* to build the knowledge base behind this video.

Figure 2: Screenshot from "Who Is Responsible For Climate Change? – Who Needs To Fix It?"



Source: video available at: available at: https://www.youtube.com/watch?v=ipVxxxqwBQw&vl=es

The original video consists of an introduction, three questions, and a conclusion. We divided the video into three chapters. The three chapters take roughly two to three

minutes. The first chapter provides general information on historical CO2 emissions of various countries, and introduces the main question of the video: who is responsible for climate change? The second chapter answers the following two questions: "which countries emit the most carbon dioxide today?" and "which countries have emitted the most in total?". The third question ("which countries emit most carbon dioxide per person?") is not taken into account in the study as this part of the video provided few possibilities for relevant manipulations. The fourth chapter provides a conclusion on which countries should take responsibility in the fight against climate change.

Survey

The survey was conducted between December 2020 and January 2021 on Prolific, a data collection platform that connects researchers with research participants. Prolific allows researchers to filter on demographic characteristics and generate a sample that is representative of either the US or the UK population in terms of gender, age and ethnicity. We collected a total of 965 complete responses (496 women) from a sample that is representative of the UK population. The mean age was 45.24 years (*SD* = 16.08). The largest ethnic/racial group was White (80%), followed by Asian (8%), Black (5%), Mixed (3%) and other (3%). Most respondents were in full-time employment (42%), and a substantial group was working part-time (17%) or not in paid work because they are home-makers, retired or have a disability (22%), and nine percent were unemployed.

Procedure

Respondents completed a short online survey of ca. 7 minutes. They accessed the survey via the data collection platform Prolific. Respondents first answered questions about their attitudes towards environmental protection as well as five knowledge questions about climate change. They were then randomly assigned to watch one of the twelve fragments of Kurzgesagt's video on climate change. The twelve conditions were extracted from the three original chapters and from nine manipulated chapters.

After watching the video, respondents answered how they perceived the video in terms of trustworthiness, reliability, engagement, and entertainment. They also answered how they perceived the narrator, the overall production and what they thought the primary aim of the video was. They then provided some relevant background information, such as participants' trust in institutions, level of religiosity and political orientation. Finally, they

answered manipulation-check questions which we included to understand whether respondents noticed and remembered the manipulations. The manipulations are explained in-depth in section 3.2. Socio-demographic information about study participants was available from Prolific for all respondents who had completed the survey.

Outcome measures

Our key outcomes measures captured perceptions of the video's trustworthiness, reliability, and engagement, which are the core values of the TRESCA project. We also measured whether the video was perceived as entertaining as entertainment is one of the main reasons why users watch YouTube videos. Also, we were interested in knowing whether producing an entertaining video would enhance or diminish its perceived reliability and trustworthiness. These four outcomes were measured on a 5-point scale (1= fully disagree; 5= fully agree) in response to the question about the extent to which participants agreed with the statements: (a) "The video was trustworthy"; (b) "The video was reliable"; (c) "The video was engaging"; (d) "The video was entertaining".

In addition to the key outcome measures, we also asked respondents what they thought the aim of the video was. They could pick as many options as they wished from the following list: (a) to inform; (b) to persuade; (c) to encourage; (d) to shock; (e) to blame; (f) to change one's behavior; (g) the video has another aim: please specify. We also asked study participants how they perceived the production value of the video on a 5- point scale, with a total of three items, namely: "The video had a high production value", "The animations corresponded well with the narrative", and "The video was created by amateurs" (reverse-coded). Furthermore, we measured on a 5-point scale how the narrator was perceived with regard to six characteristics: friendly, intelligent, competent, warm, trustworthy and skilled. With these additional outcome measures, we are able to examine whether perceptions of the narrator, aim and production go hand-in-hand with the key video perceptions of trustworthiness, reliability, engagement and entertainment. Finally, we asked respondents how they felt about the future of the planet after seeing the video on a scale from 1 (very pessimistic) to 5 (very optimistic).

Interaction and control variables

Before starting the video, respondents were asked several questions about their attitudes on climate change and their knowledge of this phenomenon. This allowed us to construct

scales which we could use as interaction variables. In other words, it enabled us to analyse whether the effects of the manipulations were stronger for respondents who 'believed' in climate change and/or had a lot of knowledge on the topic. The presence of this effect is important to confirm the presence of confirmation bias or cognitive dissonance aversion.

Besides their climate change attitudes, we also collected information on the respondents' political attitudes. On a five-point scale, respondents were asked whether they identify as leftist (1) or rightist (5). They also indicated how much (5-point scale, ranging from 'no trust at all' to 'complete trust') trust they had in the following institutions: the parliament; political parties; politicians; the police; the UN; and the legal system. Religiosity was measured by asking how religious the respondents were on a scale of 1 ('not at all religious') to 5 ('very religious').

3. Video manipulations

In total, we incorporated nine manipulations in the video, which were designed in close collaboration with Kurzgesagt. Several of these manipulations were directly inspired by practice, grounded in previous research findings, and a few manipulations were inspired primarily by theory and gaps in existing literature. The manipulations and their relevance are discussed below.

Female narrator

Multiple recent studies have demonstrated that women are perceived to be less intelligent than men (Bian et al. 2018, 1150; Storage et al. 2016). Other studies found that women tend to be perceived as more trustworthy than men (Boltz et al. 2010, 463). Because of these contrasting perceptions we examined whether the gender of the narrator affects the video's perceived trustworthiness and reliability. The original Kurzgesagt video is narrated by a male voice actor and we invited a female voice actor to re-narrate all scripts for this study.

Mentioning sources

In *Communicating the urgency and challenge of global climate change*, Susanne Moser and Lisa Dilling provide an overview of communication strategies for climate scientists and policy makers. One of their main advice is to use trusted messengers because "convincing arguments are best received if they come from highly credible and legitimate sources" (Moser and Dilling 2004: 41).

Kurzgesagt finds it important to communicate the sources their information stems from. Therefore, each video contains a source sheet in the video description on YouTube. When the topic of a video is rather controversial, or when Kurzgesagt wants to stress that sources have been used, Kurzgesagt refers to sources in the video itself. Either by making one of the characters in the video mentioning the source sheet, or by subtly displaying the source in the bottom right corner of the video. In the video that is used for this study, the latter option was used. Since some viewers might not notice this, we decided to come up with two manipulations. The first one does not contain any reference to sources, whereas the second manipulation makes these references extra visible.

Local impact

A previous study by Hart and Nisbet (2012, 717) on effective science communication found that people are more supportive of climate mitigation policies when they identify with potential victims of climate change. People are less likely to identify with others when they live in different parts of the world. Therefore, science communicators might be able to increase effectiveness by focusing on local effects. The original video mentions negative consequences of climate change for the North Pole ("Almost every year breaks some horrible record (…) and the least ice ever recorded at the North Pole"). Since the North Pole is a sparsely populated area, viewers might become more engaged if the video mentioned consequences for another area. As Kurzgesagt is a German company with many European viewers, and Prolific allowed us to specifically target respondents from the UK, we opted for Europe ("In the last hundred years, there has been a recorded increase of 1-degree Celsius in Europe. As a result, the Mediterranean is already experiencing desertification. Risks of flooding are increasing across the entire European continent.").

Repeat sceptics' assertions

Maibach et al (2008, 496) argue science communication should not repeat the assertions of skeptics of climate change before refuting it. Making an assertion without referencing false claims is claimed to be more effective. Kurzgesagt follows this advice and never repeats assertions that contrast the current scientific consensus. However, Maibach et al (2008, 496) base this claim on studies that did not concern climate change. Even though an increasing amount of people believe climate change to be the result of human activities, others think climate change is solely caused by natural developments. It could therefore be effective to debunk such claims, and examine whether this affects the video's perceived reliability. We therefore added the following two phrases to the script: "Some people argue

climate change is part of a natural weather cycle. However, scientists agree the climate is now changing at an unusual rapid speed, and humans contribute to it."

Word choice

Former US President Donald Trump once tweeted: "They changed the name from 'global warming' to 'climate change' after the term global warming just wasn't working (it was too cold)!" (@RealDonaldTrump, March 25, 2013). The truth is that scientists have used both terms interchangeably since the 1970s. Science communicators often opt for 'climate change' because 'global warming' may sound like a positive change to some individuals. Kurzgesagt follows this advice and consistently uses the phrase 'climate change'. However, Schuldt el al (2011, 120) found that conservative Americans tend to prefer 'global warming'. They are also less likely to deny the existence of the phenomenon when this term is used. Liberals are not concerned with which term is used. We therefore tested whether using the term 'global warming' results in greater levels of reliability and trustworthiness.

Personal approach

In some videos, Kurzgesagt directly approaches its viewers. This is also the case for the video that was analyzed in this study ("Things look very different if we look at individuals, like you, dear viewer"). Kurzgesagt wonders whether this personal approach affects viewers' engagement. We therefore deleted the personal approach in one of the manipulations.

Uncertainty

In a blog post of Nature (journal), Cambridge researchers provide five recommendations for science communication (Blastland et al. 2020). They argue it is important for scientists to disclose uncertainties, as 'part of telling the whole story is talking about what we don't know'. As an example, they refer to New Zealand's response to COVID-19. The country's Ministry of Health website clearly describes uncertainties, such as the likelihood of a false negative. Other countries have decided not to communicate this, as it was deemed too confusing. However, a recent study found that being explicit about uncertainty does not decrease trustworthiness (Van der Bles et al. 2020). This finding would imply that scholars and science communicators should be more transparent about the limits of their knowledge and the intrinsic uncertainty associated with certain phenomena. To examine whether this also holds in climate change communication, we have incorporated several manipulations that emphasise uncertainty. We included words such as 'around' and 'approximately', and expressed data in ranges rather than in exact numbers.

Controversy

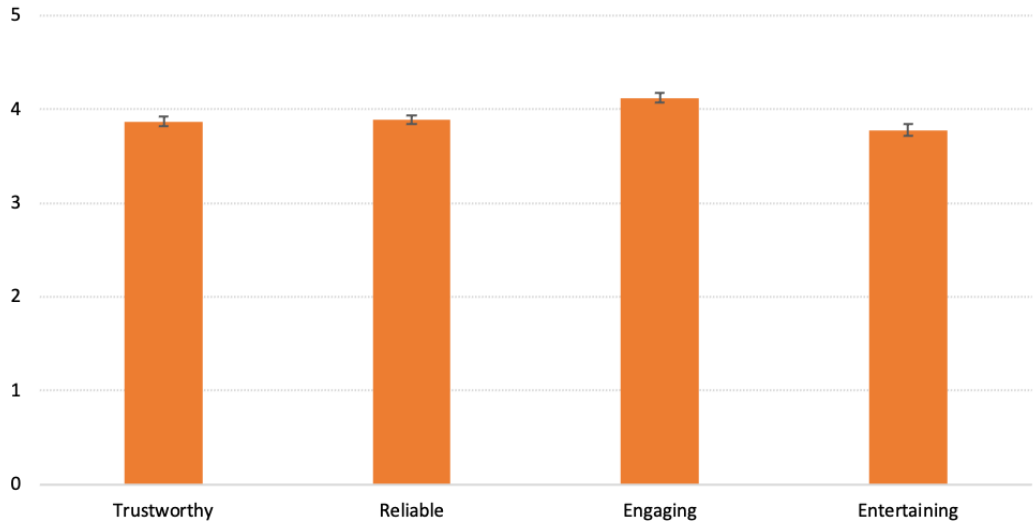
A study by the New York Times and media analysis company Zignal Labs found that Bill Gates was falsely linked to the coronavirus 1.2 million times on television or social media between February and April (New York Times, 2020). The philanthropist was accused of being the creator of the virus and of profiting from it. According to a YouGov poll, a substantial part of the US population believes Bill Gates "wants to use a mass vaccination campaign against COVID-19 to implant microchips in people that would be used to track people with a digital ID" (yougov.com, 2020). Even though these claims have no basis in reality, it is clear that Gates is perceived as a controversial figure by some people. The original video states that the video is supported by Breakthrough Energy, a coalition founded by Bill Gates. To examine whether this affects the trustworthiness of the video, we do not mention Bill Gates in the manipulated video.

4. Findings

Positive perceptions of video

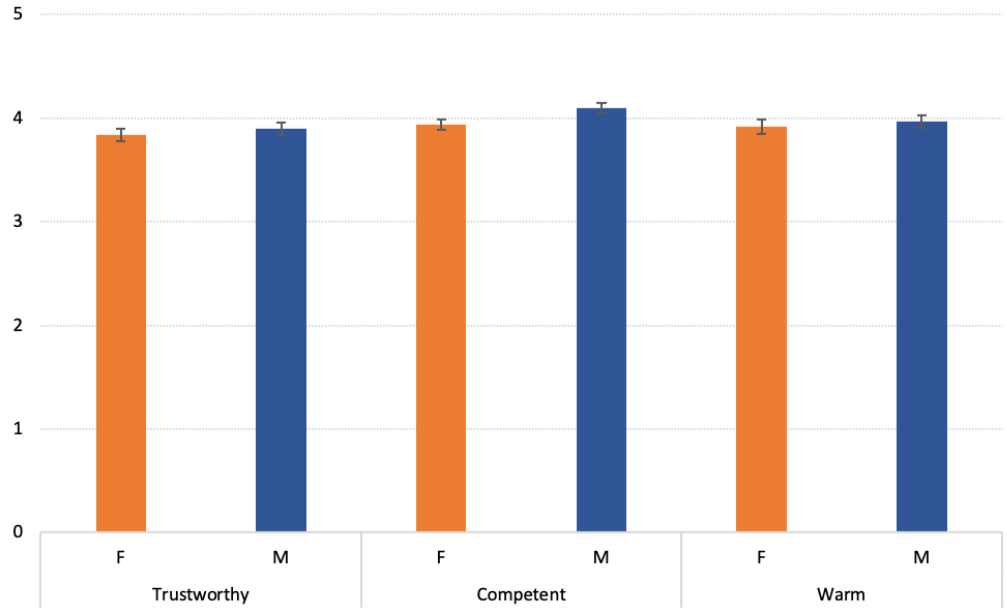
The vast majority of respondents rated positively the version of the video which was provided to them. Respondents were asked whether they perceived the video to be trustworthy, reliable, engaging and entertaining. Strong disagreement corresponds with a score of 1, while strong agreement corresponds to a 5. Figure III illustrates the average respondent gave a score of 4 ('agree') on all four measures.

Figure III: Video perceptions (with 95% confidence intervals)



The narrators were also praised. Respondents regarded them as friendly, intelligent, competent, warm, trustworthy, and skilled. Differences between perceptions of the male and female narrator are further described in the section *Narrator gender* on page 23. in All video and narrator perceptions received a score in between 3.8 and 4.1(on scale of 1 to 5), as can be observed in Figure IV.

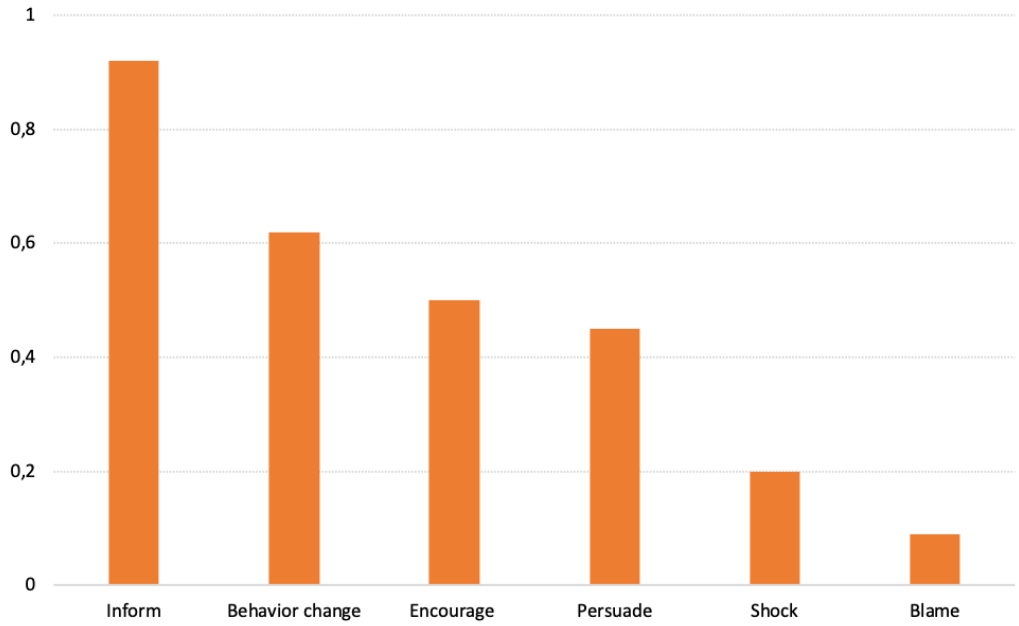
Figure IV: Narrator perceptions by gender (with 95% CI)



Perceived aims of the video

We asked the respondents to indicate what they thought the aim of the videos was. Six possible aims (informing, persuading, encouraging, shocking, blaming, and changing behaviour) were listed and respondents could tick as many boxes as they wanted. Figure V indicates the vast majority (92%) of respondents indicated that the primary aim of the video was to inform. More than half of respondents thought the aim was to change behaviour, and roughly half thought that the aim was to encourage or persuade. Twenty percent also believed that the video sought to shock, and a minority of nine percent believed that the aim was to blame.

Figure V: Perceived aim



Correlations between perceptions

Individual perceptions of the videos correlated positively with each other, meaning that a high score on one perception went hand-in-hand with a high score on another perception. For example, we observed moderate (r = 0.4) correlations between entertainment on the one hand, and trustworthiness or reliability on the other hand. In other words, respondents who perceived the video to be entertaining generally thought that the video was trustworthy and reliable as well, which indicates that science communicators should not see this as a zero-sum game.

Perceptions of the narrators also correlated positively with each other. Thus, perceived friendliness or warmth of the narrator did not go at the expense of perceived intelligence or trustworthiness. We also observed that the perceptions of the videos correlated positively with perceptions of the narrator. When respondents perceived the narrator positively, they were likely to also have a favourable perception of the video itself. None of the correlations were lower than 0.3, which is generally considered to be the cut-off point between low and moderate correlations. All correlations between the video and narrator perceptions are depicted in Table II.

Table II: Correlations between perceptions

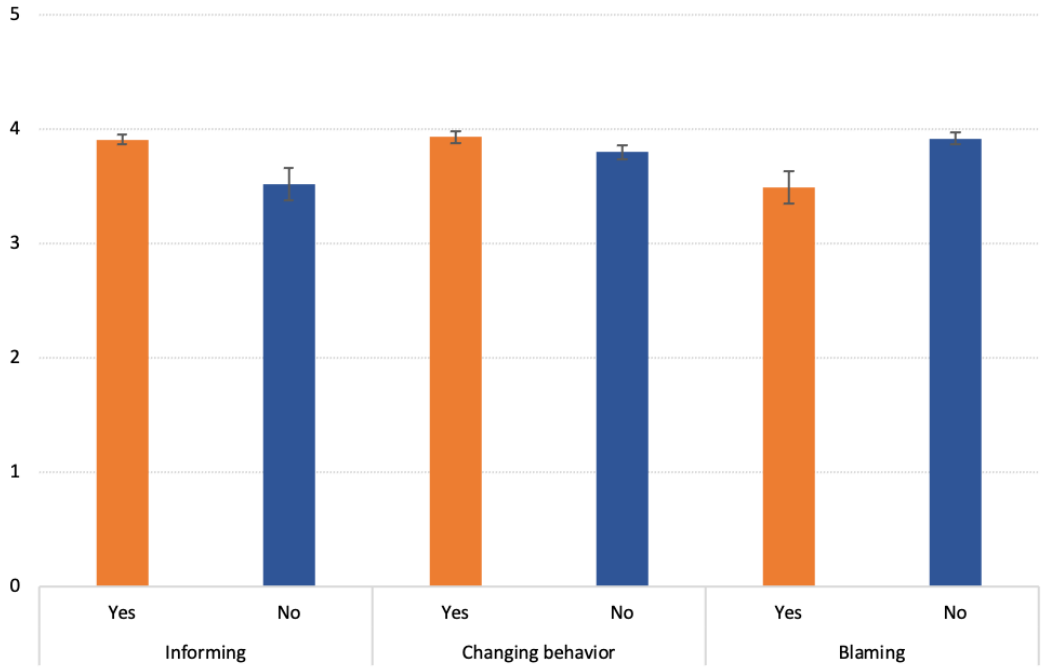
Variables	1	2	3	4	5	6	7	8	9
Video perceptions									
(1) Trustworthy									
(2) Reliable	0,8								
(3) Entertaining	0,4	0,4							
(4) Engaging	0,5	0,5	0,6						
Narrator perceptions									
(5) Friendly	0,4	0,4	0,4	0,4					
(6) Intelligent	0,5	0,5	0,4	0,5	0,5				
(7) Competent	0,5	0,5	0,3	0,5	0,5	0,7			
(8) Warm	0,4	0,3	0,4	0,4	0,8	0,5	0,5		
(9) Trustworthy	0,6	0,6	0,4	0,5	0,5	0,7	0,6	0,5	
(10) Skilled	0,5	0,4	0,4	0,5	0,5	0,7	0,7	0,5	0,6

Perceived aim and video perceptions

Respondents who believed that the aim of the video was to inform or to encourage, perceived the video to be more trustworthy than those who did not believe this. The same was true for changing behaviour, which is a remarkable finding, as this suggests that science communicators do not have to obscure their beliefs if they feel strongly about a certain topic and want to make a change.

On the other hand, science communicators should shy away from blaming. Viewers who thought the aim of the video was to blame, rated the video and the narrator significantly more negatively. This seemed to be particularly true for viewers who saw variations of the video chapter that described emissions of different countries and how they have contributed to the problem of climate change. Respondents who believed the video's aim was to blame commented in the open responses that the video was 'quite brain washing' or 'seemed to be aimed at children'. The significant effects of perceived aim on trustworthiness are displayed in Figure VI.

Figure VI: Effect of perceived aim on trustworthiness (with 95% CI)



Production value

One of the most striking predictors was the perceived production value. By perceived production value we mean the extent to which viewers believe that the video is of high quality regarding technical aspects, such as quality of resolution, professional voice-over, recording quality, sound design, detail of illustrations or smoothness of animation.

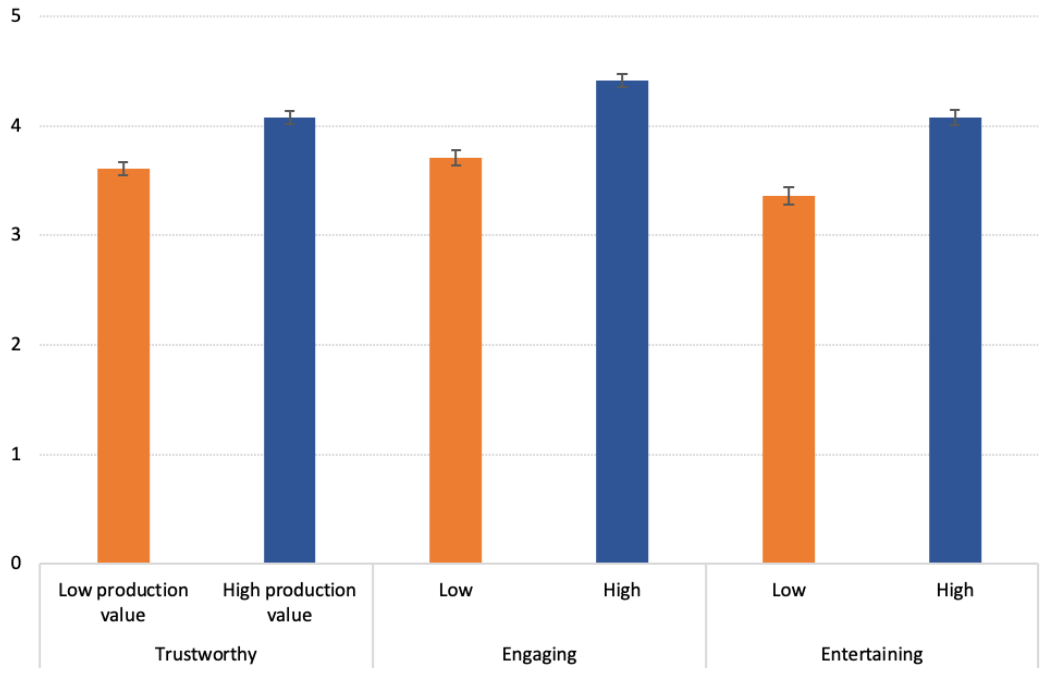
Recent research argues that being exposed to lots of video content, for example movies, tv shows, or advertisements, people are unconsciously trained to be able to tell the difference between an amateur and a more professionally produced video. This perception might serve as a heuristic of whether the creators of the video are credible.

In line with this we find that if production value was perceived to be high, then the video and the narrator were perceived more positively across all perception measures (see Fiure VII). Similarly, those who thought the production value was low were also more likely to find the quality lacking. To illustrate how these perceptions intertwine: a respondent who thought the video was untrustworthy and had a low production value commented that the video was ‘over simplistic’ and had ‘a debatable narrative’. Whereas a respondent who perceived the video to be very trustworthy and well produced wrote that the video was both ‘entertaining and informative’.

Respondents who thought that the production value was high, were more likely to think that the aim of the video was to inform, encourage and change behaviour. They less often thought that the aim was to blame.

This highlights the value of good quality and professional production. A possible interpretation is that perceived production value is a heuristic that viewers use as a proxy for their overall perception of the video. If production value is high, then this might serve as a halo: the video appears overall positive. Viewers project good intentions onto the creators and give them the benefit of the doubt.

Figure VII: Video perceptions by perceived production value (with 95% CI)



Manipulations

We incorporated several manipulations to see if they would affect respondents' perceptions of the video. We added a check in the survey to control whether respondents actually saw and remembered the manipulations. These checks varied in how many right or wrong answers participants could choose from. With one correct and one wrong answers, there is a 50% chance of guessing the right answer. When there was one correct and two wrong answers, the chance of guessing the correct answer is 0.33. Overall, participants answered the manipulation check questions correctly, above and beyond

chance. The only condition where participants did not answer the manipulation check questions as expected was the fearful message condition. The manipulation in this condition was that it ended on a negative note by stating that "Everybody needs to do the best they can. And right now, we are all not doing that. *If we don't begin soon, it will be too late*". Kurzgesagt videos often end on a positive note and as such, the original video had ended as follows: "Everybody needs to do the best they can. And right now, we are all not doing that. *But we can begin today*". Our manipulation check asked to what extent respondents thought that the video ended on a positive note and to what extent they thought that it ended on a negative note. Interestingly, the reason why so many respondents did not pass the manipulation check is because they perceived the video to end on a positive note even when it ended on a fearful message. Sixty-five percent of respondents in the fearful message condition thought that the video ended on a positive note. And only 17.5% thought that the video ended on a negative note, even though it contained the message that "if we don't begin soon, it will be too late".

Considering other manipulations, respondents seemed to have generally noticed the manipulations rather than guessing the right answer. Manipulations that were remembered well were whether sources were displayed, whether controversy was added and whether the viewer was addressed personally. However, respondents did only slightly better than chance for some conditions, which suggests that a substantial number of respondents might not have noticed or remembered the manipulations correctly. Respondents for example remembered less well whether the video focused on Europe or the world, as well as whether the narrator said "global warming" or "climate change". While this is worth noting, it does not necessarily present a problem for our experiment, because manipulations might be effective outside of viewers' conscious awareness. The manipulation checks are illustrated in Table III.

Table III: Manipulation checks

Condition	Expected mean if participants guessed	Observed mean	Difference
Sources	.33	.54	.21
Geography	.33	.48	.15
Skeptics	.50	.76	.26
Global warming	.50	.65	.15
Personal address	.50	.69	.19
Fearful message	.50	.41	-.09
Controversy	.50	.91	.41

Contrary to our expectations, we did not observe main effects of the manipulations on the video's perceived trustworthiness, reliability, or entertainment. However, when "climate change" was used as opposed to "global warming", the video was perceived as more engaging, and the narrator was perceived as significantly more trustworthy and warmer. Roughly half of the respondents made use of the opportunity to leave a comment about the video which we coded as engagement. Respondents who watched a video in which assertions of climate sceptics were mentioned and refuted were more likely to engage. We also asked respondents how optimistic they felt about the future of the planet after watching the video. The only manipulation that had an effect on optimism was the Bill Gates manipulation. When Bill Gates was mentioned, respondents felt less optimistic. The uncertainty manipulation did not cause significant effects. In other words, using uncertain terms such as 'approximately' and 'around' and presenting numbers in ranges does not confuse viewers, and subsequently decreases the perceived quality of the video.

As mentioned before, many of the respondents were not aware of the small manipulations we had made to the video. Previous research also relied on subtle manipulations; however, these were often text manipulations where the only stimulus is written text. In our case, however, respondents watched a video, which contained many stimuli: animations, audio, graphs and text. It is possible that our manipulations were too subtle to compete with the many other stimuli that participants saw and heard. Therefore, it might not be very

surprising that these manipulations had little effect on viewers' perceptions.

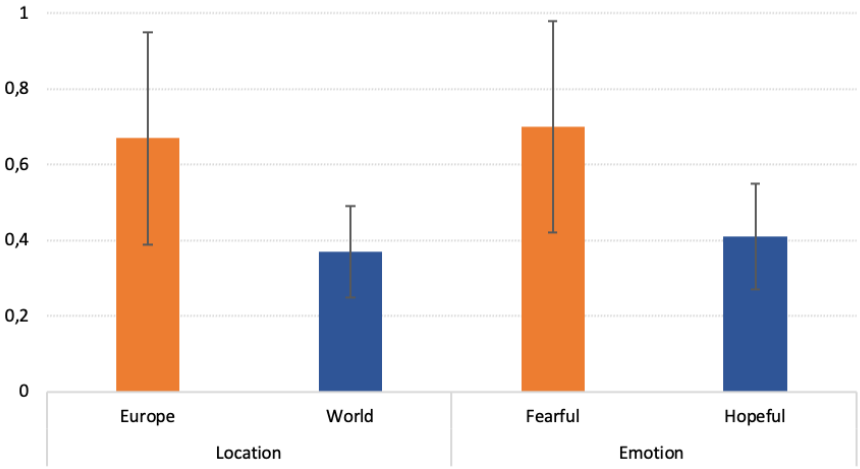
Narrator gender

The gender of the narrator did not explain variation in respondents' engagement or their degree of optimism. When the narrator was male, respondents were slightly more likely to believe that the aim of the video was to shock or to encourage them. The male and female narrator were perceived to be similar in terms of warmth and trustworthiness, but the male narrator was perceived to be more competent. This result can reflect some underlying gender bias and would require further analysis to disentangle cultural and individual effects. There was no difference in how trustworthy or engaging the video was perceived to be. Videos with the male narrator (the voice mostly used in Kurzgesagt's videos) were perceived as significantly more entertaining. It is not clear whether this effect is produced by the familiarity of the voice for those who have watched other videos produced by Kurzgesagt or if the effect is produced by the professional skills of the speaker. We tested whether these effects were associated with respondents' gender and we found no association.

Effects when manipulations were remembered

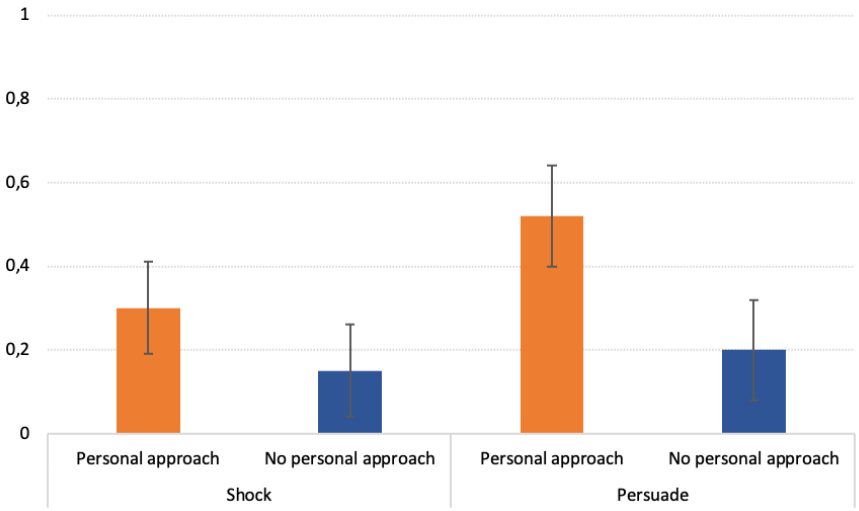
To test whether noticing and remembering the manipulations played a role, we separated participants who *did* from those who *did not* notice and remember the manipulation. Among those who noticed the manipulations, a different picture emerges. When the video specifically mentioned negative consequences of climate change for Europe, engagement increased, and more people thought the aim of the video was to encourage them. As such, it could be beneficial to address the consequences for Europe even more explicitly. The 'fearful message' manipulation also resulted in more engagement. Figure VIII illustrates the differences in engagement by remembered manipulation. The y-axis represents proportions of each group.

Figure VIII: Differences in engagement by remembered manipulation (with 95% CI)



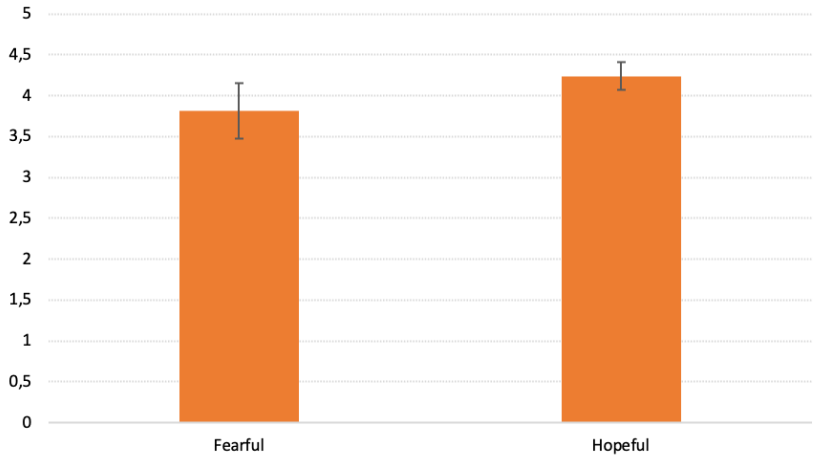
When viewers were addressed personally, they were more likely to think that the aim was to shock or to persuade, as can be deduced from Figure IX.

Figure IX: Differences in perceived aim by approach (with 95% CI)



Besides more engagement, the 'fearful message' also resulted in a decrease in perceived warmth. Thus, ending on a positive note results in a warmer perception of the narrator. This difference is depicted in Figure XI.

Figure X: Differences in perceived warmth by message (with 95% CI)



Experimental effects on video perception

In the final results section, we discuss exploratory regression models that tested for relevant moderation effects. The aim of these analyses was to examine whether effects of the experimental manipulations depended on respondents' attitudes towards climate change. In other words: were the videos perceived differently by viewers who were in favor of environmental protection compared to people who were less in favor of protecting the environment?

Description of variables. The various dependent variables for the videos perceptions reflect the extent to which the respondents find the video: 'Vtru' = trustworthy; 'Vrel' = reliable; 'Vent' = entertaining; and 'Veng' = engaging. Because these variables were highly correlated, we created an aggregate variable 'Vtresca' by averaging across the four video perception variables (Cronbach's α = .82). This variable ('Vtresca') captures general positive affect towards the video. For testing Vtresca, we employed an OLS regression. For the remaining dependent variables, we used ordered/ordinal logistic regressions.

For the independent variables, several Likert scales were aggregated. 'Prod' is the mean of a scale comprising the three variables for respondents' perception of the video's production value (Cronbach's α = .76). 'Narr' comprises the six variables measuring perceptions of the narrator (Cronbach's α = .89). 'AttCC' comprises five variables that capture the extent to which respondents believe that climate change is real (Cronbach's α = .76).

Additionally, for the following tables, 'Int' refers to the Intercept (or the 1st intercept for the ordinal logistic regressions); 'isFem' = 1 indicates that the respondent is female; 'isSFem' = 1 means that the narrator is female; 'X' refers to an experimental manipulation and the specific condition is shown in parentheses. 'AttxX' refers to the interaction between climate change attitudes and the respective manipulation. A visual depiction of the interaction effect is included in the second-to-last column. The 'R2' column contains the Adjusted-R2 when Vtresca is the DV (OLS) and Nagelkerke's pseudo-R2 for the ordinal logistic models. Each table is sorted in descending order of the R2.

Tables IV presents results for manipulations in chapter 1. We present only results that exhibited significant (or weakly significant) coefficients for main effects or interaction effects; these are presented bold-faced. Significance is indicated by *** = p < .001, ** = p < .01, * = p < .05, and ^ = p < .10. Since no Vtresca models qualify, all presented models are the ordinal logistic ones, and all coefficients are log-odds, the direction of which contributes or detracts from the probability of the predicted ordinal level being higher or lower. If the test for a coefficient corresponds to an implied hypothesis, then we present significance of one-tailed tests.

Table IV: effects chapter 1

DV	Int	age	isFem	isWhite	isSFem	Prod	Narr	AttCC	X	AttCCxX		R2
Veng	9.85***	-0.01	-0.35	-0.05	-0.15	1.79***	1.86***	0.97^	**3.22^(SrcP)**	**-0.96^**		0.578
Vtru	10.61***	0.01	-0.20	0.52	0.43	0.94*	1.90***	1.52**	**-3.41^(SrcP)**	0.68		0.563
Veng	12.61***	0.00	-0.14	0.12	0.03	2.09***	1.52***	0.94*	**3.83*(NoSrc)**	**-1.02***		0.534
Vrel	10.72***	0.01	-0.57	-0.04	**0.94***	0.32	2.58***	1.43**	2.26(Geo)	**-0.77^**		0.508
Vent	4.61*	-0.00	-0.01	0.23	**-0.73***	1.30***	0.99**	0.43	**2.63^(Geo)**	**-0.76^**		0.410
Vent	3.41	-0.01	0.22	0.23	-0.25	1.53***	0.67^	0.41	2.42(SrcP)	**-0.83^**		0.378
Vent	3.53	-0.01	-0.04	-0.00	-0.20	1.19***	0.72*	0.39	2.14(NoSrc)	**-0.63^**		0.274

Unsurprisingly, perceptions of the production value (Prod) and narrator (Narr) had positive effects on trust, entertainment, and engagement as does (the extent of one's) belief in climate change (AttCC). These three significantly predict video perceptions (at varying levels) for all reported models.

The manipulation for the inclusion of scepticism was insignificant, which is why it is omitted from Table IV. The manipulations of prominent sources (SrcP) or no sources (NoSrc) and local region (Europe) showed effects, although mixed in direction and some opposite to what we expected. We do find that inclusion of prominent sources (SrcP) enhances

engagement (Veng), particularly among those who believe less in climate change (AttCC). More generally, this means that displaying prominent sources has different effects and leads to different perceptions among people who are more supportive of environmental protection compared to those who are less supportive of it. Similarly, the mention of Europe contributed to how reliable (Vrel) and entertaining (Vent) the respondents found the video, while this effect diminished for climate change believers.

Table V: Effects chapter 2

DV	Int	age	isFem	isWhite	isSFem	Prod	Narr	AttCC	X	AttCCxX		R2
Vtru	5.15**	-0.02^	-0.43	0.54	-0.42	0.43	2.21***	0.52	**-3.19^(Unc)**	**0.98***		0.513

This finding is further supported by results from the video experiments of chapter 2 (Table V). We find that qualifying quantitative claims (i.e. being more uncertain, Unc) somewhat detracts from the video's trustworthiness. However, communicating uncertainty is slightly more appreciated by climate change believers than by those who believe less in climate change.

Table VI: Effects chapter 3

DV	Int	age	isFem	isWhite	isSFem	Prod	Narr	AttCC	X	AttCCxX		R2
Vent	5.26**	-0.04**	-0.21	-0.04	0.12	1.26***	1.67***	0.44	**2.87^(Fear)**	**-0.78^**		0.478

Finally, in the manipulations of chapter III, we find that respondents did not react to controversy as represented by the inclusion or exclusion of Bill Gates (NoBill). We therefore omitted the results from Table VI. Fearful language (Fear) enhanced the entertainment (Vent) value of chapter 3, and we again find that this effect differs depending on viewers attitudes towards climate change. However, it should be noted that the effect of fear was negligible for other video perceptions, such as trustworthiness or engagement and the aggregated affect variable.

These exploratory findings show that the same video manipulations are perceived differently by different audiences. We found this to be the case for inclusion of sources, uncertainty, and fearful messaging. Different ways of communicating affected video perceptions differently depending on whether viewers believed more or less in climate change.

5. Conclusion

Best practice I: Audience matters

Science communicators should be well aware who they are targeting as climate change attitudes affect how the videos are perceived. For example: the inclusion of prominent sources enhances engagement, but this effect is muted for those who believe more in climate change. This leads us to believe that this group is not fond of "over-the-top" stimuli. Similarly, climate change deniers are more likely to perceive the video as less trustworthy when the narrator uses uncertain terms in comparison to believers.

Best practice II: Perceived intention matters

One of the most striking findings of the study is the effect of perceived intention. When respondents believe the aim of the video is to blame, they rate it much more negatively. Therefore, science communicators should make sure their message does not come across as such. On the contrary, science communicators do not need to be too careful about coming off as wanting to change viewers' behavior. Respondents that indicated this to be the aim of the video, rated the video more positively than those who did not. The same goes for the aim to inform, and fortunately, 92% of respondents perceived this to be the intention of the Kurzgesagt video. This could be true because of several factors: the videos cover a topic rather broadly focusing on fundamentals, they pose a question in the beginning and present evidence that answers the question throughout the video, and the conclusions clearly distinguish between evidence and interpretation.

Best practice III: Production value matters

If the production value was perceived to be high, the video and narrator were perceived more positively across all perception measures. Respondents who thought the production value was low were also more likely to find the video trustworthiness or narrator lacking. This highlights the important role of production value. Video creators can achieve higher production value by investing in better quality of resolution, professional voice-over, better recording quality, sound design, detail of illustrations or smoothness of animation.

Best practice IV: Entertainment and trustworthiness can go hand-in-hand

Science communicators do not need to be hesitant about producing entertaining messages. Respondents who perceived the video to be entertaining, were more likely to say the video was also trustworthy, reliable and engaging. As a consequence, quality and entertainment should not be treated as a trade-off. On the contrary: they go hand-in hand.

Best practice V: Communicating uncertainty does not decrease perceived quality

Science is often uncertain. However, science communicators tend to think that communicating these uncertainties will confuse people and make the message less clear. We did not find many negative effects of using uncertain terms (e.g. approximately and presenting numbers in ranges) on the video's perceived trustworthiness, reliability, engagement, and entertainment. This indicates that science communicators can be honest about presenting uncertain findings. As mentioned in 'Best practice I', this does depend on the audience. We found that climate change skeptics respond more negatively to being presented with uncertain information.

Best practice VI: Changes in the narrative need to be clear and explicit

At first, it seemed like the experimental conditions had little or no effect on the respondents' perceptions . Through a check in the survey, we saw that a significant part of the respondents did not notice or remember the manipulation. In hindsight, it is not very surprising that a small change in the narrative was not picked up by many respondents. Humans process visual information better than other types of data. It would therefore be unsurprising if viewers were more focused on the visual aspect of the video than the narrative. As such, some manipulations might have been too subtle to significantly affect the viewers' perceptions of the video. Running a separate analysis in which we only included respondents who did notice and remember the manipulation did result in more significant findings. For example: participants who remembered that negative consequences of climate change for Europe were mentioned, were more engaged with the video. Based on these insights we conclude that producers of science videos should be aware that changes in the narrative need to be clear and explicit if they want to change the perception of viewers.

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7. Appendix

Original script

The text below is the original script of the Kurzgesagt YouTube video "Who is responsible for climate change? Who needs to fix it?". The manipulations that were applied to it are explained in chapter III.

"Since the Industrial Revolution, humans have released over 1.5 trillion tonnes of carbon dioxide or CO2 into the earth's atmosphere. In the year 2019 we were still pumping out around 37 billion more. That's 50% more than the year 2000 and almost three times as much as 50 years ago.

And it's not just CO2. We're also pumping out growing volumes of other greenhouse gases such as methane and nitrous oxide. Combining all of our greenhouse gases, we're emitting 51 billion tonnes of carbon dioxide equivalents each year.

And emissions keep rising – but they need to get down to 0!

In recent years the consequences have become more serious and visible. Almost every year breaks some horrible record. We've had more heat waves, the most Glaciers melting, and least ice ever recorded at the North Pole. Of the last 22 years, 20 have been the hottest on record.

The only way to limit this rapid climate change is to decrease our collective emissions, quickly. But although all countries agree on this goal in principle, they do not agree who is responsible or who should bear the heaviest load.

The developed countries point at their own efforts to reduce emissions and the fact that the large developing countries on the rise, especially China, are currently releasing much more CO2.

On the other hand, developing countries argue that emissions by the West are lifestyle emissions, while for developing countries they are survival emissions. Others call rich countries hypocrites that got rich by polluting without restraint and now expect others not to industrialize and stay poor.

So. Who IS responsible for Climate Change and CO2 Emissions? And regardless of the past, who needs to do the most today? In this video we'll talk exclusively about nation states. We'll look at the fossil fuel industry in another video.

Question 1/3 : Which countries emit the most carbon dioxide today?

In 2017 humans emitted about 36 billion tonnes of CO2. More than 50% came from Asia. North America and Europe followed with 18% and 17%. While Africa, South America and Oceania together only contributed 8%.

China is by far the world's largest emitter with 10 billion tonnes of CO2 every year or 27% of global emissions! It is followed by the USA with 15% and the European Union with around 10%.

Together this is more than half of the world's CO2 emissions. So, it is clear that without the willingness and action of these three industrial blocks, humanity will not be able to become carbon neutral and prevent severe climate change.

Next on our list is India at 7%; Russia at 5%; Japan at 3%; and Iran, Saudi Arabia, South Korea, and Canada all just short of 2%. Together with the first three, the top ten are responsible for 75% of global emissions.

But if we only look at the current situation, we are not getting the full picture:

Question 2/3 : Which countries have emitted the most in total?

If we look at emissions throughout history until today, the outlook changes drastically:

The US and the EU both knock China off the top spot.

The US is responsible for 25% of the world's historical emissions – emitting 400 billion tonnes, mostly in the 20th century. In second place is the EU at 22%. China comes in third, at just under 13%. Around half of the USA's contribution.

India's contribution shrinks to 3%, along with the whole of Africa and South America.

Within the EU, the UK is responsible for 1% of annual global emissions, but takes 5% of the historical responsibility – Germany, producing 2% of emissions per year today, has contributed almost 6%, twice as much as the whole of Africa and South America combined.

So, the narrative that rapid climate change is really the responsibility of the developing world is hard to defend if facts matter to you.

But this is still not the whole story. Because focussing on countries mixes two things: Population numbers and total emissions. If a country has more people in general its emissions are of course higher. Things look very different if we look at individuals, like you, dear viewer.

Question 3/3: Which countries emit the most carbon dioxide per person?

The average human is responsible for around 5 tonnes of CO2 each year. But averages can be misleading.

The countries with the largest CO2 emissions per person are some of the world's major oil and gas producers: 2017 Qatar had the highest emissions at an obscene 49 tonnes per person, followed by Trinidad and Tobago; Kuwait; the United Arab Emirates; Brunei, Bahrain and Saudi Arabia.

But those are outliers.

Australians have one of the highest carbon footprints per person: 17 tonnes a year. That's more than triple the global average and slightly more than the average US American and Canadian at 16 tonnes. The Germans do a little better at close to 10 tonnes, but this is still twice the global average.

China may be the world's largest emitter, but it's also the world's most populous country with over 1.4 billion people – 18.5% of the world population. Per person it is slightly above average at 7 tonnes.

Historically, CO2 emissions have been closely tied to a high standard of living. Wealth is one of the strongest indicators of our carbon footprint because as we move from poor to rich we gain access to electricity, heating, air conditioning, lighting, modern cooking, cars or planes, smart phones, computers and interact with people across the world online. The enormous rise of China's CO2 emissions is coupled with the greatest reduction of poverty in history.

If we order CO2 emissions by income, we see that the richest half of countries are responsible for 86% of global emissions and the bottom half, for only 14%. The average German emits more than five times as much as the average Indian. In just 2.3 days the average American emits as much as the average Nigerien in a year.

And not only that, the harsh reality is that it's the countries that contribute least to the problem that stand to lose the most from rapid climate change. The developing world will be hit the hardest. The consequences could be food insecurity, conflicts over resources, harsher and more frequent natural disasters, and large climate refugee movements.

Question 4/3: So who should take responsibility?

Many of today's richest countries are in a convenient position: they have become ich over centuries of fossil fuel burning and industrial production. They have a large historical footprint, and their wealth means they still emit a lot per person.

But their country's annual emissions are now dwarfed by other countries because the giant that is China is finally catching up and other giants like India are on their way.

Many Germans for example wonder how, if Germany "only" accounts for 2% of yearly emissions, it can have a meaningful impact on reducing emissions?

The answer is simple: For one, the richest countries have the resources, highly educated workforces, and technology to develop low-cost, low-carbon solutions and spread them around the world.

If we don't want poorer countries to become as fossil fuel dependent as we are, we need low-carbon technology to be cheap and available. And we're getting there: the cost of renewables is falling quickly, and a variety of solutions are on the horizon for many different sectors. But it needs to happen much faster.

If the rich countries of the west decide to seriously tackle rapid climate change the rest of the world would follow because it has no choice. Just like when the European Union enforced energy efficiency standards for technology, the rest of the world adopted them too because they wanted to be able to continue trading with the bloc.

Still, this doesn't absolve others of their responsibility. China is the largest CO2 emitter today and it is China's responsibility to grow in a way that will make it possible to transition to a zero-carbon world in time. Others acting irresponsibly yesterday is a horrible excuse for repeating the same mistakes today.

Climate change is a global problem and no country alone can fix it. Working out who is responsible is not as simple as it seems and in a way, it is a daft question, but one that has plagued international politics for decades. In the end it is pretty simple:

Everybody needs to do the best they can. And right now, we are all not doing that.

But we can begin today.

This video is part of a series about climate change supported by Breakthrough Energy – a coalition founded by Bill Gates, that is working to expand clean-energy investment and support the innovations that will lead the world to net-zero carbon emissions. Also, a special thanks to the team at Our World in Data for helping us out with data and research!"

Manipulated script

The script below provides clarity on the exact changes that were made in the manipulated videos. Manipulation I (sources) is not mentioned as this is a purely visual manipulation. Screenshots of this manipulation are displayed at the end of the script. Question 3/3 is in a light font as we did not incorporate this part in the experiment.

"Since the Industrial Revolution, humans have released over 1.5 trillion tons of carbon dioxide or CO2 into the earth's atmosphere. In the year 2019 we were still pumping out around 37 billion more. That's 50% more than the year 2000 and almost three times as much as 50 years ago.

And it's not just CO2. We're also pumping out growing volumes of other greenhouse gases such as methane and nitrous oxide. Combining all of our greenhouse gases, we're emitting 51 billion tons of carbon dioxide equivalents each year.

And emissions keep rising – but they need to get down to 0!

Manipulation II: *The consequences are already horrible and right in front of our door. In the last hundred years, there has been a recorded increase of 1-degree Celsius in Europe. As a result, the Mediterranean is already experiencing desertification. Risks of flooding are increasing across the entire European continent.*

Manipulation III: *Skeptics argue climate change is not man made but part of a natural weather cycle that is beyond our control. However, almost all scientists agree the climate is now changing at an unusually rapid speed, and humans contribute to it. Of the last 22 years, 20 have been the hottest on record.*

The only way to limit this rapid climate change is to decrease our collective emissions, quickly. But although all countries agree on this goal in principle, they do not agree who is responsible or who should bear the heaviest load.

The developed countries point at their own efforts to reduce emissions and the fact that the large developing countries on the rise, especially China, are currently releasing much more CO2.

On the other hand, developing countries argue that emissions by the West are lifestyle emissions, while for developing countries they are survival emissions. Others call rich countries hypocrites that got rich by polluting without restraint and now expect others not to industrialize and stay poor.

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Manipulation VI: *In 2017 humans emitted about 36 billion tonnes of CO2. It is estimated that more than 50% came from Asia. North America and Europe followed with around 18% and 17%. While Africa, South America and Oceania together only contributed approximately 8%.*

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Together this is more than half of the world's CO_2 emissions. So, it is clear that without the willingness and action of these three industrial blocks, humanity will **[Manipulation VI]** *most probably* not be able to become carbon neutral and prevent severe **[Manipulation IV]** *global warming*.

Next on our list is India at 7%; Russia at 5%; Japan at 3%; and Iran, Saudi Arabia, South Korea, and Canada all just short of 2%. Together with the first three, the top ten are responsible for 75% of global emissions.

But if we only look at the current situation, we are not getting the full picture:

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[Manipulation VI] *The US is believed to be responsible for around 25% of the world's historical emissions* – emitting 400 billion tonnes, mostly in the 20th century. In second place is the EU at 22%. China comes in third, at just under 13%. Around half of the USA's contribution.

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The UK is responsible for 1% of annual global emissions, but takes 5% of the historical responsibility – Germany, producing 2% of emissions per year today, has contributed almost 6%, as much as the whole of Africa and South America combined.

So the narrative that rapid **[Manipulation IV]** *global warming*.is really the responsibility of the developing world is hard to defend if facts matter to you.

But this is still not the whole story. Because focusing on countries mixes two things: Population numbers and total emissions. If a country has more people in general its emissions are of course higher. **[Manipulation V]** ~~Things look very different if we look at individuals, like you, dear viewer.~~

Question 3/3: Which countries emit the most carbon dioxide per person?
Chapter III (2:40)

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And not only that, the harsh reality is that it's the countries that contribute least to the problem that stand to lose the most from rapid climate change. The developing world will be hit the hardest. The consequences could be food insecurity, conflicts over resources, harsher and more frequent natural disasters, and large climate refugee movements.

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Many of today's richest countries are in a convenient position: they have become rich over centuries of fossil fuel burning and industrial production. They have a large historical footprint, and their wealth means they still emit a lot per person.

But their country's annual emissions are now dwarfed by other countries because the giant that is China is finally catching up and other giants like India are on their way.

Many Germans for example wonder how, if Germany "only" accounts for 2% of yearly emissions, it can have a meaningful impact on reducing emissions?

The answer is simple: For one, the richest countries have the resources, highly educated workforces, and technology to develop low-cost, low-carbon solutions and spread them around the world.

If we don't want poorer countries to become as fossil fuel dependent as we are, we need low-carbon technology to be cheap and available. And we're getting there: the cost of renewables is falling quickly, and a variety of solutions are on the horizon for many different sectors. But it needs to happen much faster.

If the rich countries of the west decide to seriously tackle rapid climate change the rest of the world would follow because it has no choice. Just like when the European Union enforced energy efficiency standards for technology, the rest of the world adopted them too because they wanted to be able to continue trading with the bloc.

Still, this doesn't absolve others of their responsibility. China is the largest CO2 emitter today and it is China's responsibility to grow in a way that will make it possible to transition to a zero-carbon world in time. Others acting irresponsibly yesterday is a horrible excuse for repeating the same mistakes today.

Climate change is a global problem and no country alone can fix it. Working out who is responsible is not as simple as it seems and in a way, it is a daft question, but one that has plagued international politics for decades. In the end it is pretty simple:

Everybody needs to do the best they can. And right now, we are all not doing that.

Manipulation VII: ~~But we can begin today.~~ *If we don't begin soon, it will be too late.*

This video is part of a series about climate change supported by Breakthrough Energy – a coalition **[Manipulation VIII]** ~~founded by Bill Gates~~, that is working to expand clean-energy investment and support the innovations that will lead the world to net-zero carbon emissions. Also, a special thanks to the team at Our World in Data for helping us out with data and research. "

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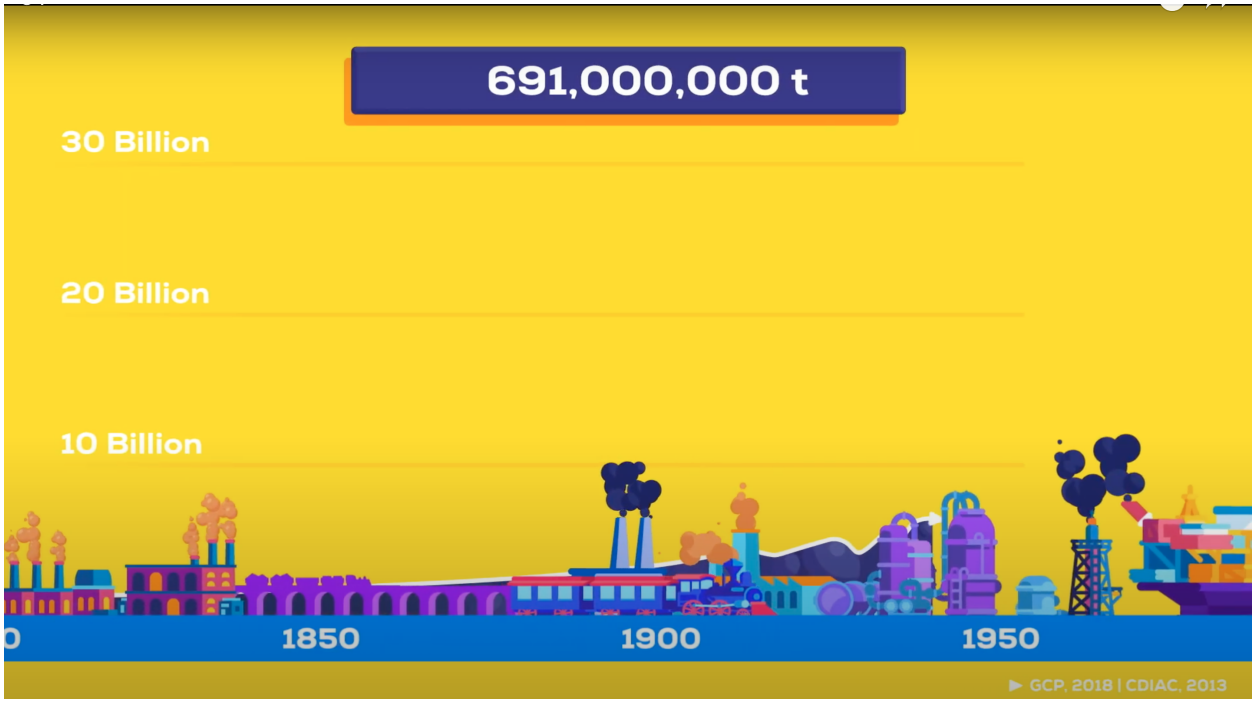

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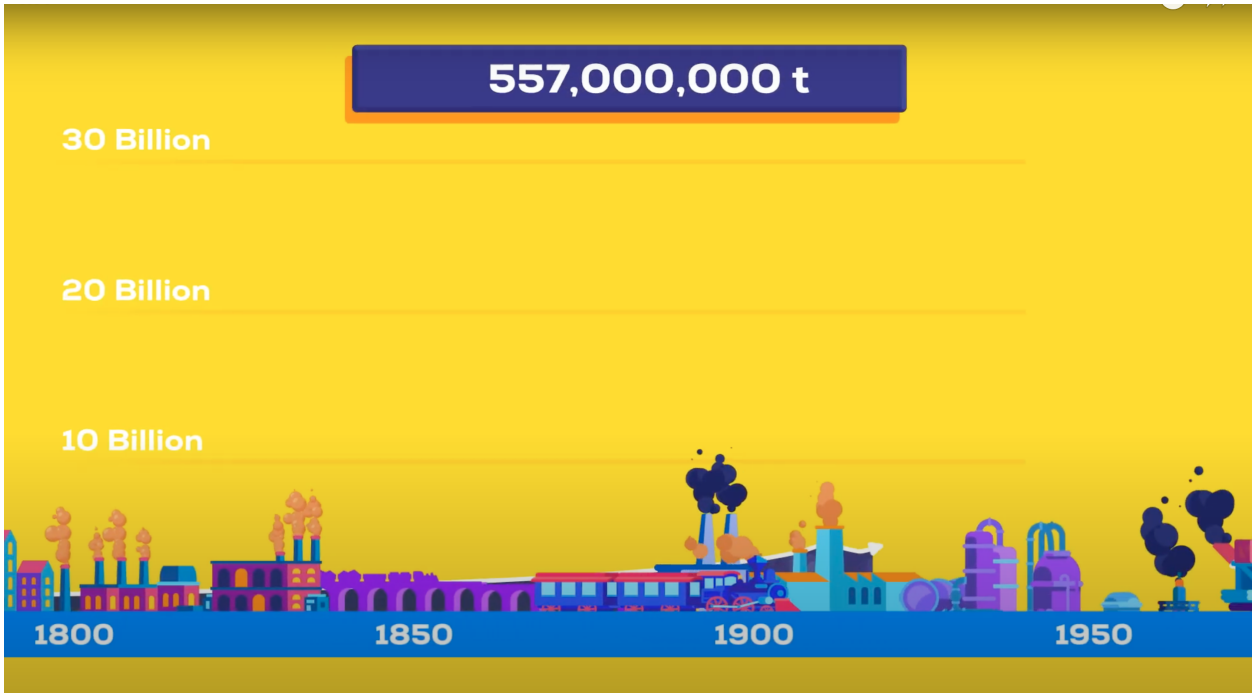

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