universität wien

MASTERARBEIT / MASTER'S THESIS

Titel der Masterarbeit / Title of the Master's Thesis

"'Being Simple on Complex Issues' – An Expert Account of Visual Data Communication of Climate Change"

verfasst von / submitted by

Regina Maria Veronika Schuster, BSc

angestrebter akademischer Grad / in partial fulfilment of the requirements for the degree of

Master of Science (MSc)

Wien, 2022 / Vienna, 2022

Studienkennzahl lt. Studienblatt / degree programme code as it appears on the student record sheet:	UA 066 926
Studienrichtung lt. Studienblatt / degree programme as it appears on the student record sheet:	Masterstudium Wirtschaftsinformatik
Betreut von / Supervisor:	Univ. Prof. Torsten Möller, PhD
Mitbetreut von / Co-Supervisor:	Laura Koesten, MSc PhD

Abstract

Despite overwhelming scientific consensus concerning the threatening impact of climate change, public understanding on the topic seems to lack depth. Widely known alarming prognoses on the one hand coexist with limited public engagement on the other hand. Data visualizations play a critical role in both communicating scientific evidence about climate change and in stimulating engagement and action. To investigate how visualizations can be better utilized to communicate the complexities of climate change to different audiences, we conducted interviews with 17 experts in the fields of climate change, science communication and data visualization. We use our findings to derive implications and recommendations for creating more effective visualizations, particularly in news media sources geared toward lay audiences. Implications include the establishment of an iterative, user-centered co-design process, the adaption of contents according to the needs of the audience, and the integration of information and formats which users can relate to. We further discuss the role of storytelling, aesthetics, uncertainty representation, and interactive techniques in the visual communication of climate change.

Kurzfassung

Trotz des überwältigenden wissenschaftlichen Konsens über die bedrohlichen Auswirkungen des Klimawandels scheint es dem öffentlichen Verständnis für das Thema an Tiefe zu fehlen. Auf der einen Seite sehen wir weit verbreitete alarmierende Prognosen und auf der anderen Seite begrenztes öffentliches Engagement. Datenvisualisierungen spielen sowohl bei der Übermittlung wissenschaftlicher Erkenntnisse über den Klimawandel als auch bei der Förderung von Engagement und Handeln eine entscheidende Rolle. Um zu untersuchen, wie Datenvisualisierungen genutzt werden können um die Komplexität des Klimawandels verschiedenen Zielgruppen zu vermitteln, haben wir 17 Expert*innen aus den Bereichen Klimawandel, Wissenschaftskommunikation und Datenvisualisierung interviewt. Aus den Erkenntnissen der Interviews leiten wir Implikationen und Empfehlungen für die Erstellung effektiverer Visualisierungen, insbesondere im Hinblick auf Nachrichtenmedien und Laienpublikum, ab. Implikationen umfassen die Verwendung eines iterativen, benutzerzentrierten Co-Design-Prozesses, die Anpassung von Inhalten an die Bedürfnisse der Zielgruppe und die Einbindung von Informationen und Formaten, zu denen der Leser einen Bezug hat. Weiterhin diskutieren wir die Rolle von Story-Telling und Ästhetik, sowie die Darstellung von Unsicherheiten und interaktive Techniken im Bezug auf Datenvisualisierungen zum Thema Klimawandel.

Contents

Abstract i

Kurzfassung iii

1. Introduction 1

2. Research Background 5
2.1. The Design Space of Climate Change Data Visualizations 5
2.2. Climate Change Data Visualizations by the IPCC 6
2.2.1. Simplification vs. Accuracy 6
2.2.2. Understandability for the IPCC's Target Audience 6
2.2.3. Creating Effective IPCC Visuals 7
2.3. Climate Change Data Visualizations in News Media 8
2.3.1. Contents and Public Perception 8
2.3.2. Understandability for Lay Audiences 9

3. Methodology 11
3.1. Participants 11
3.2. Example Visualizations 13
3.3. Interview and Analysis Procedure 17

4. Results 21
4.1. Climate Change Communication to the Public 21
4.1.1. We Need to Act 21
4.1.2. Climate Change Is Complex 22
4.1.3. News Media Sources Play a Pivotal Role 23
4.2. Climate Change Data Visualizations 24
4.2.1. Communicating Data Visually Comes with Benefits 24
4.2.2. Quality Depends on the Purpose 25
4.2.3. We Need to Teach Data Visualization and Climate Change 27
4.3. Implications for Creating Effective Climate Change Data Visualizations . 28
4.3.1. Embrace the Process 28
4.3.2. Embrace the Audience 28
4.3.3. Make it Simple, but Transparent 29
4.3.4. Make it Relatable 30
4.3.5. Tell a Clear Story 31
4.3.6. Make it Attractive 32

4.3.7. Adapt Uncertainty Representations to the Audience 33
4.3.8. Make it Interactive, Only if it Fits the Users' Needs 34

5. Discussion and Conclusion **35**
5.1. It's All about the Audience 35
5.1.1. "Why Should I Care?" – Ensuring Interest and Relatability 36
5.1.2. "What Does that Mean?" – Ensuring Understandability 37
5.2. Tension between Simplicity and Accuracy 38
5.3. A Complex, Urgent, and Inconvenient Message 39
5.4. Limitations and Future Work 39
5.5. Conclusion 40

Bibliography **41**

A. Appendix **49**
A.1. Selection of Example Visualizations 49
A.2. Participant Information and Declaration of Consent 53
A.3. Overview of the Results 58

1. Introduction

The latest climate science report published by the Intergovernmental Panel on Climate Change (IPCC) [32] painted a bleak picture of the future. In the contribution of Working Group I to the Sixth IPCC Assessment Report, the physical science basics of climate change were presented in the light of the latest level of scientific knowledge. Main messages include: "It is unequivocal that human influence has warmed the atmosphere, ocean and land" [32, p. 4], "Many changes due to past and future greenhouse gas emissions are irreversible for centuries to millennia, especially changes in the ocean, ice sheets and global sea level" [32, p. 21], and "Global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in CO_2 and other greenhouse gas emissions occur in the coming decades" [32, p. 14]. While the scientific consensus in this field of research has been strong, the newest IPCC report reveals that climate change is happening faster and with more serious consequences than previously assumed. It is incontestable that we are already experiencing the effects and consequences of global warming all around the globe and that some of these changes are already irreversible. However, we sure can influence how the future will look like by taking action. For example, reducing carbon dioxide and other greenhouse gas emissions drastically in the next years would have a vast impact on air quality and global temperatures. On the other hand, if not enough action is taken now, consequences for society and the earth are expected to be devastating including warming oceans, rising sea levels and more frequent and intense weather extremes like droughts, storms, or heat waves.

Despite overwhelming scientific consensus concerning the threatening impact of climate change, public understanding on the topic seems to lack depth. Widely known alarming prognoses on the one hand coexist with limited public engagement on the other hand. A 2021 survey by Pew Research Center [60] found that while the majority of the general public in first world countries is concerned that climate change and its consequences will harm themselves personally in the future, 27% of the respondents claim to be not too, or not at all, concerned. These statistics vary notably among countries with South Korea (88%) or Greece (87%) showing a relatively high level of concern compared to the U.S. (60%) or Sweden (44%). However, since 2015 the percentage of respondents that are very concerned that the consequences of the changing climate will harm them personally has increased greatly in a number of major economies (e.g. + 19% points in Germany, from 18% in 2015 to 37% in 2021). The increasing global concern about the threat of climate change is also reflected in the peoples' openness to change their own behavior: While a promising 80% of respondents show the willingness to make a lot or some changes about their lifestyles in order to fight climate change, about 19% is not or hardly willing to change their behavior.

Aside from private engagement, especially decision makers in corporate or political positions would be able to create a large impact by facilitating and implementing substantial climate mitigation policies. However, also corporate and political engagement needed to affect change in climate issues may also not be sufficient. While companies and politicians around the world have definitely included climate matters in their agendas, concrete action plans are often less ambitious than they sound. "What's Really Behind Corporate Promises on Climate Change?" – this question was asked by the New York Times reporters Peter Eavis and Clifford Krauss in their 2021 article [11] in which they elaborate on businesses' goals to cut their greenhouse gas emissions. While many companies have not even released a plan to reduce their impact on climate change, some of those who did, seem to keep their promises remarkably vague according to their research. Sustainability reports might sound great, but the actual targets are often not comprehensive enough to make a real difference. They quote the Institutional Shareholder Services, who did an analysis to investigate what the 500 companies in the S&P 500 stock index are doing or planning to do in order to reduce their emissions. While approximately a third of those companies have set ambitious goals, they found that 215 had not set any target at all, and the rest only having weak targets. The State of Climate Action 2021 Report published by the World Resources Institute [3] states that despite individual sectors/regions/companies/cities etc. proving that substantial progress in climate change matters is possible, "much more could be achieved if all decision makers around the world gave climate action the high priority it is due" [3, p. 3]. They further claim that far-reaching transformation activities across all sectors and regions are necessary to prevent worst-case scenario impacts of global warming. While some sectors are said to have a rather clear insight into what technologies and practices are needed to cut emissions and are simply missing the necessary investments and political support, in other industries also a lack of understanding might be the reason for the hesitation.

A lack of understanding about the scientific evidence of climate change was also previously suspected as a reason for the lack of public concern [34]. Climate change is a wicked problem [28], involving complex relationships between environmental and social factors. At the same time, climate change research relies on vast amounts of heterogeneous data [33, 57] which are used to create and test models, often with a high degree of uncertainty attached. The complexity of the topic coupled with the mixture of data, methods, and the use of models make communication to different audiences a challenge. Even though an extensive part of existing research has focused on the communication about climate change through textual forms, climate change communication is witnessing a trend toward visual formats in practice and in research [22, 56]. Researchers have investigated the impact of photos [67], films [40], and the role of social media [44, 59] in developing effective forms of communication on the topic.

The growing importance of visuals has lead to various ways of visualizing climate matters with the contentious 'hockey stick' curve on global temperatures being one of the best-known examples [43, 67]. While climate change imagery is the focus of much research (e.g. [9, 52]), less work focuses specifically on climate change data visualizations, i.e. charts,

graphs or maps. As visual representations of data are crucial in communicating the science behind climate change to decision makers and the public [66], the study of how to design climate change data visualizations and how people interpret them is of critical importance.

This study investigates how different experts think visualizations can be better utilized to communicate the complexities of climate change to different audiences; we also aim to derive implications for the creation of effective climate change data visualizations. We address the following two research questions: i. What are common challenges people face when interpreting data visualizations about climate change? ii. How can data visualizations about climate change be designed to support factors such as readability, understandability and trustworthiness? To seek expert opinions on those research questions, we interviewed 17 participants with expertise in either climate change, science communication, or data visualization. As a discussion prompt in the in-depth interviews, we showed participants two visualizations from the Sixth Assessment Report published by the Intergovernmental Panel on Climate Change (IPCC) [32]. We also showed them corresponding representations of the same graphics reproduced in newspaper sources. The IPCC is the United Nations body for assessing the science related to climate change. As such, it prepares comprehensive and regular scientific assessment reports for policy makers with updates about climate change, its implications, and mitigation options. In addition to being the primary resource for translating climate change science to policy makers, it is also used as the basis for public discourse on the topic [10].

We use findings of the interviews to derive implications for creating more effective visualizations, particularly in news media sources geared toward lay audiences. Key implications include the establishment of an iterative, user-centered co-design process, the adaption of contents according to the needs of the audience, and the integration of information and formats which users can relate to. We further discuss the role of storytelling, aesthetics, uncertainty representation, and interactive techniques in the visual communication of climate change. This work therefore contributes to the existing literature by providing:

- in-depth expert insights about the role of climate change data visualizations and how visualizations can be improved
- a better understanding of how to cater climate change data visualization to different audiences
- implications relevant for a range of data visualization creators, i.e. educators, policy makers, domain experts, journalists, practitioners and the visualization community.

2. Research Background

The growing importance of data visualizations in the field of climate change is visible in practice as well as in current research with sources of climate change data visuals spanning a broad range of creators. Climate researchers, governmental and non-governmental environmental organizations and agencies, climate activists, advertisers, local stakeholders, artists or news media sources are all stakeholders who are involved in the visual politics of climate change [78]. After a short overview over literature covering the design space of climate change data visualizations, we review research investigating climate change data visualizations from two common sources: the Intergovernmental Panel on Climate Change (IPCC) and news media outlets.

2.1. The Design Space of Climate Change Data Visualizations

Despite the relevance of effective visualization solutions, little research so far has focused on investigating the design space of climate change data visualizations from different sources. While some reflections focus on single aspects of the topic (e.g. [33], [68]) and others compare specific types of visualizations to other means of communication (e.g. [72] compare pie charts to texts or metaphors), only few authors have investigated the design space of climate change data visualizations as a whole. Windhager et al. [77] analyzed a diverse sample of climate change visualizations in order to explore their feature and design space. The selected visualizations focused on the development of temperatures (or CO_2 levels) over time and made use of at least one information visualization technique with non-expert users as the main target audience. The resulting set of climate change visualizations was categorized according to their group/type affiliation. Six groups or types of climate change data visualizations were identified: Line charts, circular line charts, other temperature visualization techniques, colored maps, multi-view interactive visualizations, and visualizations focusing on CO_2. While for temperature representations, line charts and colorized maps were found to be the most prominent visualization techniques, time was usually represented by a linear, spatial dimension (in 1, 2, or 3-dimensional spaces) or by using animation or color to visualize periods of time. Nocke et al. [51, 70] took another approach to explore the design space of climate change data visualizations: Instead of collecting a sample of visualizations according to specific criteria, they interviewed researchers about their usage of visualization techniques. With 2.5 and 3-D visualizations being of less importance, most respondents used 2-D visualizations, including time charts (90%), bar charts (77%), 2D maps (66%), and scatter-plots (56%), most frequently.

2.2. Climate Change Data Visualizations by the IPCC

The IPCC publishes regular assessments summarizing the latest science related to climate change. With 195 member countries and thousands of contributing climate scientists and experts, the IPCC is a reliable source of scientific knowledge [31]. While data visualizations, such as charts or graphs, have become an integral part of climate change communication, the IPCC also emphasizes the importance of visualizations for their communication strategy: "graphics form the cornerstone of the information provided by the IPCC" [30, p. 2-04], with line graphs being one of the most common visual design choices of IPCC authors [78]. The importance of visuals in IPCC publications has also been studied scientifically. Pidcock et al. [61] conducted an online survey and semi-structured interviews where they investigated how IPCC authors try to engage non-expert audiences with climate change topics. Among other principles of communication, the respondents named the use of effective visualizations as a key factor in public engagement, with 35% of respondents mentioning IPCC figures and 21% naming scientific data-driven figures as tools to facilitate understanding. Furthermore, 12% of the respondents expressed that there is a need for simplifying IPCC data visualizations to make them accessible to lay audiences.

2.2.1. Simplification vs. Accuracy

The IPCC itself has acknowledged that non-expert readers often struggle to interpret data visualizations correctly [6]. However, creating data visualizations that are both scientifically correct and accessible for non-expert readers is not trivial: "visual science communication on climate change has always been walking a thin line between scientific accuracy on the one hand and reducing complexity for public understanding and engagement on the other" [78, p. 136]. Additionally, visualizations typically fulfill a variety of functions including depicting complex facts and simulated projections, providing guidelines to (non-expert) decision makers and conforming to aesthetic principles [78]. Harold et al. [25] conducted interviews with IPCC authors to investigate how IPCC visualizations were created. Results show that the balance between making visuals more accessible and maintaining scientific accuracy is often a challenge. By questioning both IPCC authors and a group of students, it was found that IPCC authors are generally aware of the level of comprehension difficulty in their visuals. Further analysis suggested that a higher complexity of the data visualizations is associated with greater perceived comprehension difficulty. The authors suggest appropriate computational approaches and user testing to tackle the challenge of decreasing complexity while maintaining scientific accuracy.

2.2.2. Understandability for the IPCC's Target Audience

In order to create effective visual representations of climate change data, it is key that the target audience is able to interpret them correctly. With the IPCC reports taking a crucial role in informing non-climate-expert decision makers and visualizations being a cornerstone of communication in these reports, IPCC authors aim at creating visualizations that are

accessible for lay audiences. Some of the research in the area focuses on identifying how understandable IPCC graphics appear to be for representatives of their intended audiences. Fischer et al. [13] examined the objective (accuracy) and subjective (self-assessment) understandability of three specific visualizations from the health chapter of the IPCC's Fifth Assessment Report. Respondents included a sample of visitors of the 2016 United Nations Climate Change Conference, as well as a sample of students. With a mean of 0.33 for the conference attendees and 0.38 for the student sample, the presented graphs showed a low objective understandability. Beyond that, the self-assessment of respondents from the conference sample was increasingly inaccurate, meaning that they were wrong about their assessment about which graphs they interpreted correctly. Furthermore, Fischer et al. [14] evaluated graph comprehension among (political) decision makers from 54 countries and junior diplomats from Germany by using two IPCC graphs, which either employed or violated principles of intuitive design. The findings reveal that the counter-intuitive visualization was systematically misinterpreted, while the intuitive visualization was mostly interpreted correctly. McMahon et al. [46] investigated one particular visualization published by the IPCC, namely the scenario graph depicting the global surface temperature development for the 21st century according to different simulated emission scenarios. In-depth interviews with representatives of the IPCC's Summary for Policymakers' target audience were used to test how people perceive the uncertainties displayed in this graph and its caption. While uncertainties result from both socio-economic scenarios and response uncertainty as a result of imperfect knowledge and models, they found that lay audiences had difficulties to identify these types of uncertainties in the visualization. The authors suggest that the design choices made when creating visualizations highly influence how readers perceive the graph and interpret its scientific message.

2.2.3. Creating Effective IPCC Visuals

Scholars have also investigated how IPCC data visualizations should be created to make them understandable and hence most effective. Harold et al. [24] have been investigating the fields of cognitive and psychological science to derive implications for the creation of more accessible climate change visualizations. While these evidence-informed guidelines comprise an extensive set of directives spanning the areas of directing visual attention, reducing complexity, supporting inference-making, and integrating text with graphics, some of them read: "Provide knowledge to viewers about which features of the graphic are important to look at", "Only include information that is needed for the intended purpose of the graphic", or "Use text to help direct viewers' comprehension of the graphic" [24, p. 1085]. Those guidelines have been used to rework an exemplary IPCC graphic and the original as well as the alternative version has been tested on expert and non-expert users. Results showed that 80% of the participants expressed a preference for the alternative version which was created in compliance with the guidelines. Furthermore, Harold et al. [23] introduce four key pillars that IPCC authors should consider to create clear and accessible data visualizations: message, audience, design, and evaluation. First, IPCC authors should identify a clear message for the visual to express. While assessing the

target audience's prior knowledge is essential for incorporating their needs into the visual, using design formats the audience is familiar with helps the readers with understanding. Finally, visualizations should be tested by members of the target audience and revised accordingly. The IPCC's increased engagement with creating more effective visuals seems to have already paid off: while IPCC graphics have been criticized for being inaccessible for non-specialists in the past [24], the reactions to the visuals presented in the "Climate Change 2021: the Physical Science Basis" report were much more positive [18]. Climate scientist Ed Hawkins wrote: "One key development since AR5 was the involvement of professional graphic designers in creating the figures for the Summary for Policymakers (SPM). As a result, the graphics are clear and usable, having been user-tested through several design iterations" [27].

2.3. Climate Change Data Visualizations in News Media

Besides the IPCC consolidating the science behind climate change, it is undisputed that news media outlets also play an important role in communicating climate change to the public. With a substantial part of the research toward the different sources of climate change content investigating common news media outlets, the acknowledgment of the importance of visual communication seems to be finding its way into research and practice. Despite the increasing importance of social media platforms and their multi-media approaches compared to traditional news media sources, so far text-based studies are still outweighing the visual analyses in terms of climate change content [59]. Likewise, also in practice visual communication of climate change has only become more prominent in the recent decades. In a longitudinal analysis of climate change imagery in print media sources, O'Neill [52] examined over a thousand images published in UK and US newspapers between 2001 and 2009. Results show that visualizations of climate change topics experienced a rapid increase after the year of 2005. It was also found that scientific data visualizations, i.e. charts, maps or infographics, were fairly uncommon during that time. The previously mentioned analyses of the design spaces of climate change data visualizations [51, 77] do not focus solely on news media sources.

2.3.1. Contents and Public Perception

Most of the research covering climate change visuals depicted in news media sources can be attributed to two areas: The contents and the public perception of climate change visualizations. While the former area of research has been studying the themes and frames of climate change imagery in popular news sources from a content perspective (e.g. [29, 52, 54, 62, 63, 76]), the latter focuses on the public perception of climate change visuals and peoples' engagement with them (e.g.[2, 5, 12, 26, 48, 53, 55, 73]). However, most of the research addresses the use of imagery in general and lacks a clear distinction of data visualizations such as graphs or charts. A rough differentiation between types of visualizations was conducted by Duan et al. [9], when they investigated how the level of concreteness of climate change images affects the users' perception. Therefore,

they presented abstract as well as concrete imagery to a sample of U.S. American adult respondents. While the set of concrete imagery consisted of colorful photographs depicting people in a situation that emphasizes certain aspects of climate change, the abstract imagery selection included black-and-white non-photographic images (e.g. satellite images, cartoons, charts, tables) emphasizing the causes and consequences of climate change. The authors found that the use of concrete visualizations does not necessarily result in increased levels of concern or behavioral intentions among the respondents, but can even lead to contrary effects for some people. Even though previous research showed that abstract imagery tends to leave viewers with a feeling of distance [8], this research suggests that concrete imagery like photographs is not necessarily more effective than abstract imagery like data visualizations.

2.3.2. Understandability for Lay Audiences

Besides this focus on climate change imagery, their contents and user perception, not much is known about climate change data visualizations used in news media formats and their understandability for lay audiences. Analyses that investigate the accessibility of graphs, charts, or maps about climate change often use visualizations published by the IPCC (e.g. [13, 14, 46]), rather than visualizations that can be found in commonly used news sources, like newspapers. In general, studies with a clear focus on climate change data visualizations from different sources and for different audiences are still scarce.

3. Methodology

To address this gap in research, we conducted an interview study with the goal of seeking expert opinions on important aspects of climate change communication to different audiences. In 17 semi-structured interviews participants with expertise in the areas of climate change, science communication, or data visualization were asked to share their opinions about climate change communication in general as well as climate change data visualizations including aspects like sources, quality, benefits, drawbacks, understandability and potential difficulties on the readers' side. The study was approved by the ethics committee of the University of Vienna.

3.1. Participants

We used purposive sampling within an expert network to contact participants. Participants were selected according to their expertise in one of the three following fields: climate change, science communication, or data visualization. Further inclusion criteria were a proficient level of the English language, diversity factors, and the willingness to engage in a recorded interview. Interviewees received no compensation for their participation. The participant information sheet, which was used to inform the potential participants about the purpose and the procedure of this study, as well as the declaration of consent form can be found in Section A.2. A total of 17 participants from Europe and North America were interviewed, from which 6 had a climate change, 6 a science communication, and 5 a data visualization background. In terms of the number of interview participants, we exceed the threshold at which data saturation normally occurs in interview studies [17, 21]. Participant's age ranges are shown in Figure 3.1; participants' job roles and research areas/disciplines span a number of different areas, as can be seen in Table 3.1.

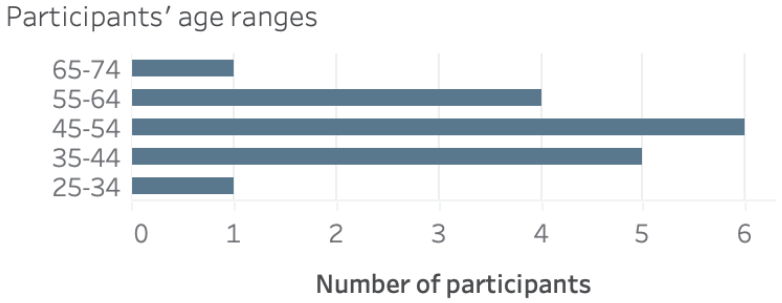

Figure 3.1.: Participants' age ranges

Table 3.1.: Participants' self-reported job roles & research areas/disciplines

Job role	**Research area**
Climate change experts (CC)	
Director of a Climate Research Institute, IPCC author	Climate/ocean modeling
Department Head of Sociology	Territorial dimension of social policies
Professor for Climate Science	Physical climate science
Sociologist	Environmental issues
Professor, Faculty Vice Head	Environmental science
Professor in European Ethnology	Urban anthropology
Science communication experts (SC)	
Researcher, Chief Scientific Officer	Modeling and simulation
Head of Communications	Communication
Professor in Social Science Methodology	Political science
Company Head	Communication
Creative Director	Design, advertising
CEO of an Information Design Firm	Information design
Data visualization experts (VIS)	
Research Scientist	Data visualization & analytics
Retired Visualization Researcher	Data visualization
Professor of Visual Data Science	Data visualization, explainable AI
Professor in Visualization	Visualization
Professor	Visualization

Interviewees from all three groups were asked about their expertise in the other two fields, for example, participants with a climate change background were asked to rate their (professional) experience in science communication and data visualization on a scale from 1 (very low) to 10 (very high). Table 3.2 shows an overview of the median values within each expert group.

Table 3.2.: Participants' self-reported expertise rated on a scale from 1 (very low) to 10 (very high), median values of all participants in a group

	Expertise (median values)		
Expert group	CC	SC	VIS
Climate change (CC)	10	7	6
Science communication (SC)	4	10	7
Data visualization (VIS)	3	7	10

3.2. Example Visualizations

During the interviews, two pairs of climate change data visualizations were used as a basis for discussion about aspects like quality, readability/understandability, or trustworthiness. The example visualizations were selected according to the following logic: the Summary for Policy Makers of the Working Group I contribution to the IPCC's Sixth Assessment Report "Climate Change 2021: The Physical Science Basis" (AR6-WGI-SPM) [32] includes ten central data visualizations explaining the latest science insights behind climate change. We investigated 85 of the most popular online news sources from the UK, the USA, and Germany for articles that were released in response to this publication. Those 85 news sources were selected according to statistics from Pressgazette.co.uk [41, 42, 69, 71] and Statista.com [37, 74, 75]. The articles were retrieved through a Google search using the search term: "ipcc 2021 site: «*news medium website link*»". The first page of search results was inspected for relevant articles. Selection criteria for the articles included:

- The article was published by the news medium in question
- The article was released in direct response to the publication of the AR6-WGI-SPM on the 9th of August 2021
- The article is not about a comment from a specific person (e.g. a politician) or about an opinion of the article's author
- The article is not focused on one specific aspect of climate change or on a specific region but is a sole report of the publication
- The article is free of charge to read and allows access from the EU

The resulting 152 articles were then investigated for data visualizations. An overview of the inspected articles is shown in Section A.1 in the Appendix, highlighting if data visualizations were used and if so, if they were copies of the IPCC's visualizations or if they were recreated by the news source. For the sake of completeness, all articles were included in this overview, even if access was denied or no data visualizations were included. Figure 3.2 shows an overview of the 10 data visualizations of the AR6-WGI-SPM and their usage in the inspected news articles.

FIGURES IN AR6-WGI-SPM	Figure name by IPCC	SPM.1	SPM.2	SPM.3	SPM.4	SPM.5	SPM.6	SPM.7	SPM.8	SPM.9	SPM.10
	Title abbreviation by authors	GLOBAL-TEMP	WARMING-CONTRIBUTIONS	REGIONAL-CHANGES	FUTURE-EMISSIONS	GLOBAL-CHANGES	EXTREMES	CO2-EMISSIONS	CC-INDICATORS	REGIONS	CO2-AND-WARMING
	Figure discription by IPCC	History of global temperature change and causes of recent warming	Assessed contributions to observed warming in 2010–2019 relative to 1850–1900.	Synthesis of assessed observed and attributable regional changes	Future anthropogenic emissions of key drivers of climate change and warming contributions by groups of drivers for the five illustrative scenarios used in this report.	Changes in annual mean surface temperature, precipitation, and soil moisture.	Projected changes in the intensity and frequency of hot temperature extremes over land, extreme precipitation over land, and agricultural and ecological droughts in drying regions.	Cumulative anthropogenic CO2 emissions taken up by land and ocean sinks by 2100 under the five illustrative scenarios.	Selected indicators of global climate change under the five illustrative scenarios used in this report.	Synthesis of the number of AR6 WGI reference regions where climatic impact-drivers are projected to change.	Near-linear relationship between cumulative CO2 emissions and the increase in global surface temperature.
Total: 85 sources	SUM (ALL)	12	2	0	8	9	7	0	9	0	0
	SUM (RECREATIONS)	10	0	0	6	4	5	0	9	0	0

Figure 3.2.: Overview of data visualization usage in the investigated 85 news sources (number of articles that included a copy or a recreation of those visualizations)

While five of the original ten data visualizations in the Summary for Policy Makers (SPM) were rarely depicted in news media sources (SPM.2, SPM.3, SPM.7, SPM.9, SPM.10), the other five were more heavily used (as copies and recreations). SPM.1, SPM.4 and SPM.8 were recreated most often. We picked two example visualizations of the more frequently used and recreated ones for inclusion in the interview discussion (SPM.1 and SPM.4). Hence the participants were provided with both the recreation from a news article, as well as the original visualization created by the IPCC. Figure 3.3 (recreation by BBC News at bbc.co.uk/news [45]) and Figure 3.4 (original by the IPCC [32]), as well as Figure 3.5 (recreation by The Guardian [20]) and Figure 3.6 (original by the IPCC [32]) show the two pairs of example visualizations.

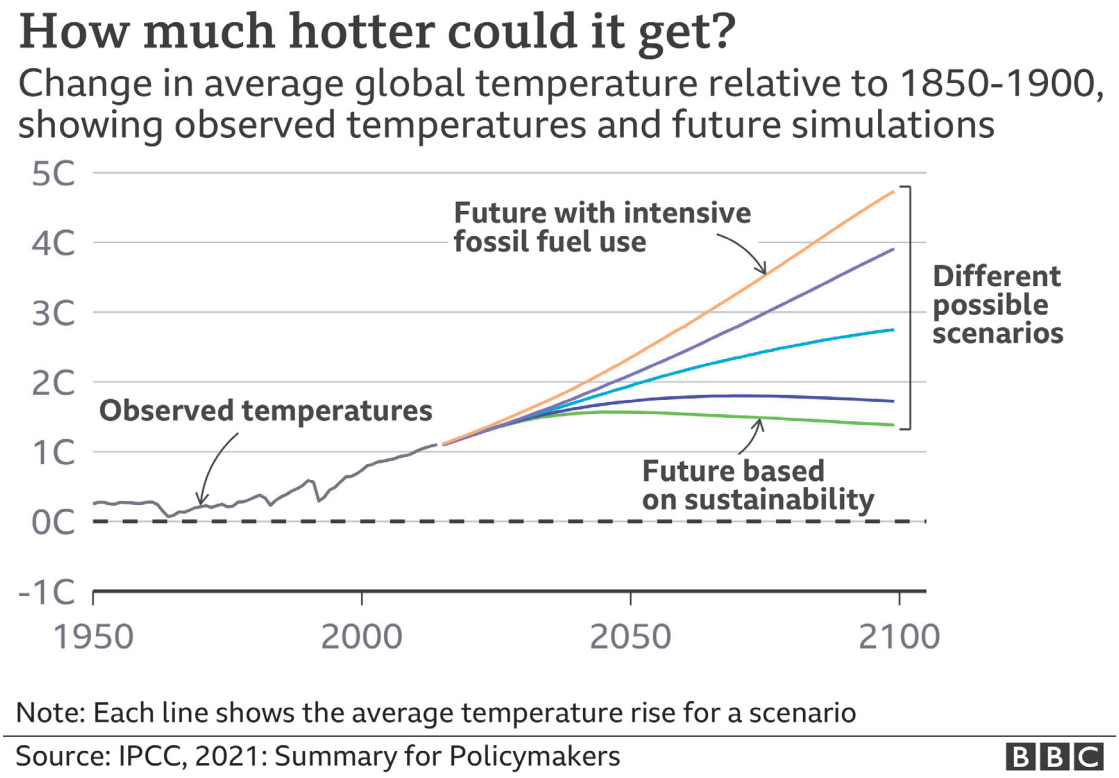

Figure 3.3.: Visualization in response to the release of the IPCC's AR6-WGI created by BBC News at bbc.co.uk/news [45]

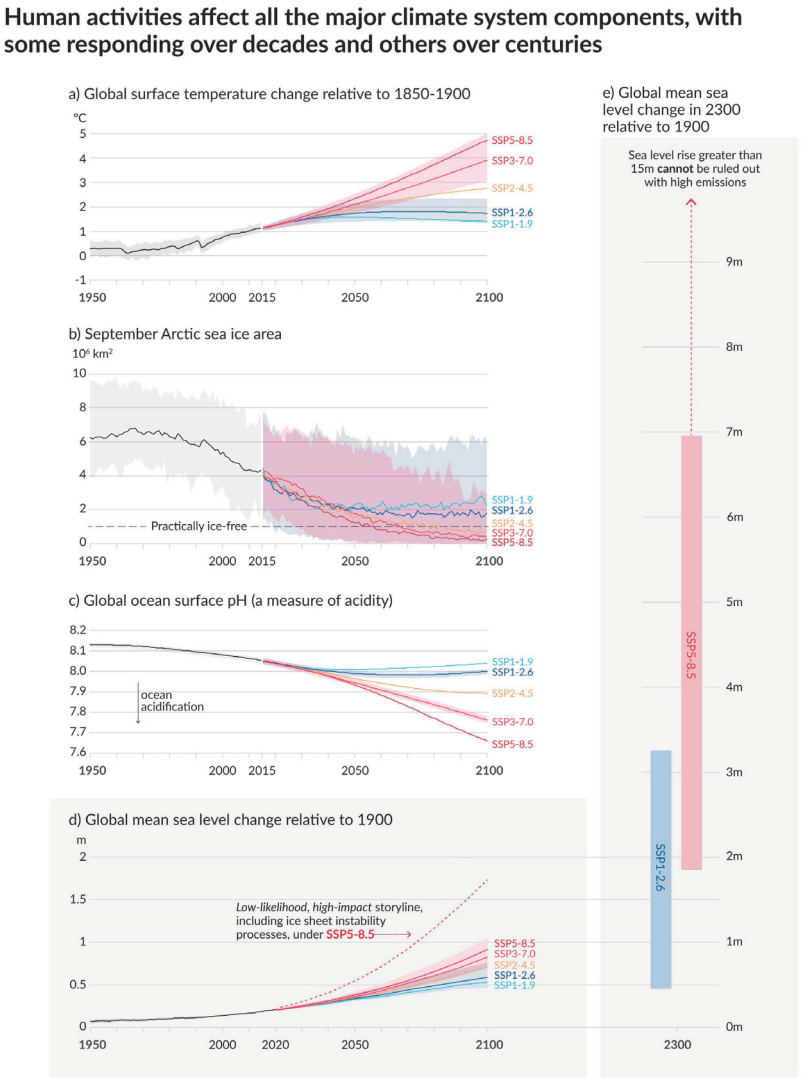

Figure SPM.8 | Selected indicators of global climate change under the five illustrative scenarios used in this Report

The projections for each of the five scenarios are shown in colour. Shades represent uncertainty ranges – more detail is provided for each panel below. The black curves represent the historical simulations (panels a, b, c) or the observations (panel d). Historical values are included in all graphs to provide context for the projected future changes.

Panel (a) Global surface temperature changes in °C relative to 1850–1900. These changes were obtained by combining Coupled Model Intercomparison Project Phase 6 (CMIP6) model simulations with observational constraints based on past simulated warming, as well as an updated assessment of equilibrium climate sensitivity (see Box SPM.1). Changes relative to 1850–1900 based on 20-year averaging periods are calculated by adding 0.85°C (the observed global surface temperature increase from 1850–1900 to 1995–2014) to simulated changes relative to 1995–2014. *Very likely* ranges are shown for SSP1-2.6 and SSP3-7.0.

Panel (b) September Arctic sea ice area in 10^6 km² based on CMIP6 model simulations. *Very likely* ranges are shown for SSP1-2.6 and SSP3-7.0. The Arctic is projected to be practically ice-free near mid-century under intermediate and high GHG emissions scenarios.

Panel (c) Global ocean surface pH (a measure of acidity) based on CMIP6 model simulations. *Very likely* ranges are shown for SSP1-2.6 and SSP3-7.0.

Panel (d) Global mean sea level change in metres, relative to 1900. The historical changes are observed (from tide gauges before 1992 and altimeters afterwards), and the future changes are assessed consistently with observational constraints based on emulation of CMIP, ice-sheet, and glacier models. *Likely* ranges are shown for SSP1-2.6 and SSP3-7.0. Only *likely* ranges are assessed for sea level changes due to difficulties in estimating the distribution of deeply uncertain processes. The dashed curve indicates the potential impact of these deeply uncertain processes. It shows the 83rd percentile of SSP5-8.5 projections that include low-likelihood, high-impact ice-sheet processes that cannot be ruled out; because of *low confidence* in projections of these processes, this curve does not constitute part of a *likely* range. Changes relative to 1900 are calculated by adding 0.158 m (observed global mean sea level rise from 1900 to 1995–2014) to simulated and observed changes relative to 1995–2014.

Panel (e) Global mean sea level change at 2300 in metres relative to 1900. Only SSP1-2.6 and SSP5-8.5 are projected at 2300, as simulations that extend beyond 2100 for the other scenarios are too few for robust results. The 17th–83rd percentile ranges are shaded. The dashed arrow illustrates the 83rd percentile of SSP5-8.5 projections that include low-likelihood, high-impact ice-sheet processes that cannot be ruled out.

Panels (b) and (c) are based on single simulations from each model, and so include a component of internal variability. Panels (a), (d) and (e) are based on long-term averages, and hence the contributions from internal variability are small.

{4.3; Figures 4.2, 4.8, and 4.11; 9.6; Figure 9.27; Figures TS.8 and TS.11; Box TS.4, Figure 1}

Figure 3.4.: Figure “SPM.8” from the Working Group I Contribution to the Sixth Assessment Report of the IPCC (AR6-WGI-SPM) [32]

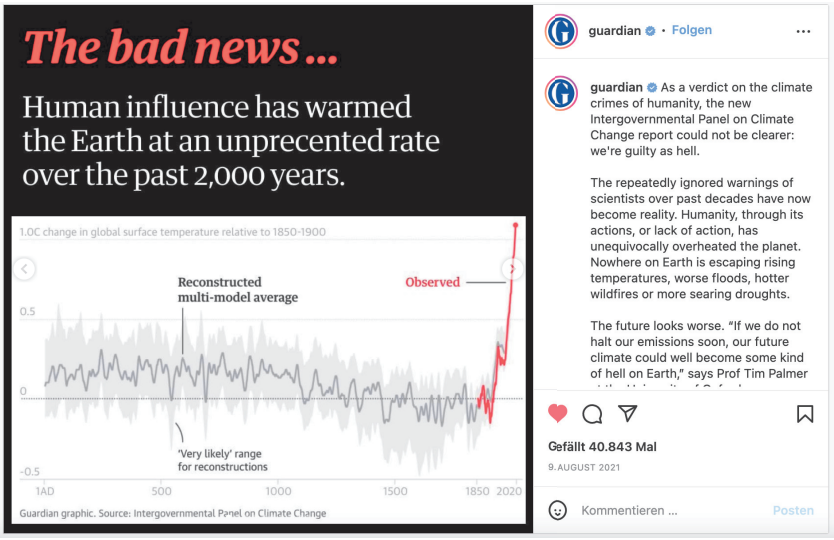

Figure 3.5.: Visualization in response to the release of the IPCC's AR6-WGI created by The Guardian [20]

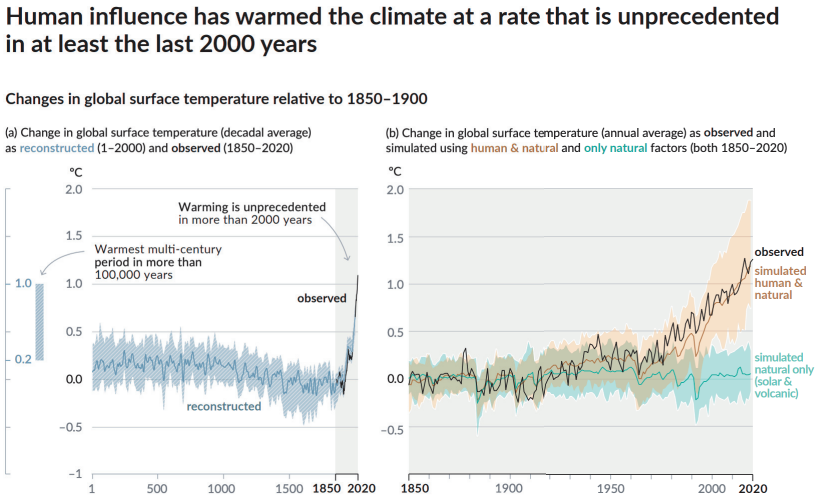

Figure SPM.1 | History of global temperature change and causes of recent warming

Panel (a) Changes in global surface temperature reconstructed from paleoclimate archives (solid grey line, years 1–2000) **and from direct observations** (solid black line, 1850–2020), both relative to 1850–1900 and decadally averaged. The vertical bar on the left shows the estimated temperature (*very likely* range) during the warmest multi-century period in at least the last 100,000 years, which occurred around 6500 years ago during the current interglacial period (Holocene). The Last Interglacial, around 125,000 years ago, is the next most recent candidate for a period of higher temperature. These past warm periods were caused by slow (multi-millennial) orbital variations. The grey shading with white diagonal lines shows the *very likely* ranges for the temperature reconstructions.

Panel (b) Changes in global surface temperature over the past 170 years (black line) relative to 1850–1900 and annually averaged, compared to Coupled Model Intercomparison Project Phase 6 (CMIP6) climate model simulations (see Box SPM.1) of the temperature response to both human and natural drivers (brown) and to only natural drivers (solar and volcanic activity, green). Solid coloured lines show the multi-model average, and coloured shades show the *very likely* range of simulations. (See Figure SPM.2 for the assessed contributions to warming).

{2.3.1; Cross-Chapter Box 2.3; 3.3; TS.2.2; Cross-Section Box TS.1, Figure 1a}

Figure 3.6.: Figure "SPM.1" from the Working Group I Contribution to the Sixth Assessment Report of the IPCC (AR6-WGI-SPM) [32]

3.3. Interview and Analysis Procedure

The online interviews were conducted and recorded via Zoom, took 30 to 60 minutes each and followed a set structure (the detailed interview schedule is displayed in Table 3.3):

- *Introduction and consent*
- *Demographics:* Data about the participants' job role, research area or discipline, age, and expertise was collected.
- *Climate change:* Climate change experts were asked about their opinion concerning climate change topics, awareness/understanding among the public and actions taken by companies and governments to react to climate change. This was the only section, that was adapted for the specific expert groups.
- *Climate change data visualizations:* Participants were asked about their opinion concerning the quality of climate change data visualizations used in common news sources, as well as about benefits and drawbacks of using data visualizations when communicating climate change topics.
- *Example visualizations:* Depending on time, either one or two pairs of example visualizations were shown to the participants as a discussion basis. Questions included aspects of quality, understandability, improvement potential and personal preference concerning the original and the newspaper version.
- *People's sense-making:* Independent of the shown example visualizations, participants were asked about their opinion concerning the understandability of climate change data visualizations, needed background knowledge for their interpretation, and common interpretation difficulties for lay audiences.

The interviews were transcribed and analyzed using the qualitative data analysis software Atlas.ti. Codes were created by systematically going through the interview transcriptions and identifying themes. With a total of 260 resulting codes, the interviews were analyzed a second time to ensure correct assignment. The codes were structured according to the following groups: demographics, climate change, climate change communication, data visualization, example visualization pair 1, and example visualization pair 2. A list of the results can be found in Section A.3 in the Appendix.

Table 3.3.: Interview schedule

Introduction and consent
Background
What is your job role and what discipline or research area do you associate with?
If you are comfortable sharing that, what is your age?
Could you tell us a bit about your professional experience in the context of climate change?
To what degree do you occupy yourself with data visualization and science communication topics?
How would you rate your experience with data visualization on a scale from 1 (low) to 10 (high)?
How would you rate your experience with science communication on a scale from 1 (low) to 10 (high)?
Climate change topics (only climate change experts)
In your opinion, what are the main climate change topics currently?
What do you think are the most important messages in terms of research results that people need to know about in order to improve the public discourse on this topic?
In your opinion, what are the main consequences of climate change on our society?
How would you rate the general awareness or understanding among the public concerning climate change and its consequences on a scale from 1 (low) to 10 (high)? If low: What do you think is the reason for this lack of awareness?
What academic journals or also non-academic media outlets for the general public (like newspapers, magazines) do you think are important in the context of climate change?
Which role do you think companies and governments could play or are already playing in fighting climate change?
How would you rate the efforts by companies and governments to react to climate change on a scale from 1 (low) to 10 (high)? If low: What do you think are the reasons for these low efforts? Do you think a lack of awareness or understanding plays a role in economic and political settings?
Role of science communication (only science communication experts)
What do you think is the role of science communication when it comes to the public discourse about climate change?
Role of data visualization (only data visualization experts)
What do you think is the role of data visualization when it comes to the public discourse about climate change?

Climate change data visualizations

If you saw an article about climate change, for example in a newspaper, would you first read the text or look at the data visualization?

Do you think common news sources like newspaper articles should make greater or less use of data visualizations?

What do you think are the benefits of using visualizations when communicating climate change topics?

What do you think are the drawbacks of using visualizations when communicating climate change topics?

How would you rate the quality of climate change visualizations used in popular news sources (e.g. television, newspapers, social media) on a scale from 1 (low) to 10 (high)? If low: How could they be improved?

What do you think about interactive data visualizations? Are there any benefits or drawbacks?

Discussion of example visualizations

→ *Showing the newspaper version of the visualization (Figure 3.3)*

In your own words, can you summarize the main message of the visualization?

Would you say the creator of this visualization did a good job depicting the main message?

Why do you think it would be easy or difficult for people without prior knowledge about climate change and data analysis/statistics to interpret this data correctly?

What could be improved about the visualization in order to enhance its readability/understandability and trustworthiness?

→ *Showing the IPCC version of the visualization (Figure 3.4)*

Please have a look at this visualization depicting the same data. Which visualization do you like better and why?

→ *Depending on time, repeat questions for the second pair (Figure 3.5 and Figure 3.6)*

Peoples' sensemaking

Would you say it is rather easy or difficult for people to interpret visualizations about climate change correctly? Why?

What do you think are common mistakes?

What kind of background knowledge is needed to interpret common visualizations correctly in your opinion? To what extent is this taught in university settings, in your opinion? Do you think the curriculum is suitable to enable students to interpret data visualizations correctly?

Debrief

4. Results

The codes were aggregated into broader themes, which are used to structure the findings: climate change communication to the public in general, climate change communication facilitated by data visualizations, and implications/recommendations. The numbers in parentheses show how many participants mentioned a specific aspect. Quotes are listed with a pseudonym indicating participant expertise: CC for climate change, SC for science communication, VIS for data visualization.

4.1. Climate Change Communication to the Public

In the course of the interviews, climate change experts (6) were asked to name the most urgent climate change topics of the moment. Two mentioned communication as one of the most important aspects. This section summarizes the main findings in terms of climate change communication to the public in general.

4.1.1. We Need to Act

> *"It's most important to understand that we need to act now. And we need swift action and we need massive action. That if we hesitate to act now, and that's actually what's happening, then the burden for the next generations and generations to come will be extremely hard."* – CC-5

According to the climate change experts, extreme events (4), migration (2), and changes concerning the economic (2) and health (1) situation count among the main consequences of climate change. The complexities and inequalities of those impacts were also apparent: while 4 interviewees mentioned that the consequences of climate change highly depend on the region, some participants claimed that socially weaker groups will be affected worse than others (4).

"I can imagine that the cultural consequences would be as complex as climate change itself." – CC-4

Climate change experts were asked what they think are the most important messages people need to understand about climate change. The answers give a sense of the urgency of the issue and the need for action: we need to act now (1); everybody can do something (2); or substantial changes are necessary (2) are some of the messages the participants regarded as most important. In addition, participants named the issue of responsibility or taking action (4) and mitigation policies (4) as important components when asked

about the main climate change topics currently. Participants with different expertise also mentioned the need to act:

"If you really want to change something, it will hurt. Yeah, there's no free lunch anymore." – VIS-4

Participants rated the efforts of companies and governments to address climate change on a scale from 1 (very low) to 10 (very high). With a median rating was 5, participants suggested some opportunities for improvement. Five participants mentioned the necessity of regulations for fighting climate change. The lack of action by individuals (2) is also an issue, with a change of consumption habits (2), such as eating meat (2) or using climate-friendly transportation alternatives (3) being examples of how citizens could help.

"I would say that it's not done enough, definitely not, by nobody, not by governments and not by companies." – CC-2

"One of the missions should be [...] to make people more aware of the implications of their acting. [...] I have friends that are eating meat twice a day from large, intensive production lines. So people don't care and don't think about the implications of every single act." – CC-2

The results suggest that comprehensive and fast action is needed. Even though these questions were only posed to climate change experts, participants from other groups also commented on the urgency to act.

4.1.2. Climate Change Is Complex

> *"It's just a very complex topic. And unless you're willing to spend serious time on thinking about it, I believe it's just hard to get your head around."* – CC-1

All but one climate change expert rated the awareness/understanding among the public concerning climate change and its consequences below 5, on a scale from 1 (low) to 10 (high). 3 participants differentiated between awareness and understanding, rating awareness considerably higher than understanding. Reasons for this lack of understanding include limited attention spans (2) and the complexity of climate change (3), which was also mentioned as a reason for the low efforts from companies and governments in fighting climate change (1).

"People are becoming increasingly aware that it is important. But at the same time, they don't take the necessary steps to address the issues that they can take in their own hands." – CC-2

According to the interviews, awareness seems to be improving, but understanding among the public concerning climate change was rated fairly low. Results indicate that one reason for this might lay in the fact that climate change is an inherently complex

topic. Without being asked, both the lack of understanding as well as the complexity of the topic was mentioned by non-climate experts as well.

4.1.3. News Media Sources Play a Pivotal Role

"It's about ways of translating, or making that knowledge accessible and communicate in a way that people can relate to it, which is not happening in academic journals." – CC-3

We asked CC experts "What academic journals or also non-academic media outlets for the general public (like newspapers, magazines) do you think are important in the context of climate change?" Four of the 6 CC experts mentioned the irrelevance of scientific sources for the general public. Participants emphasized the essential role of news media (3) and social media (2) for the public discourse about climate change, as well as the importance of training journalists in science communication (4) and securing science communication funding (1).

"I guess academic journals [are] almost not important at all for communicating with the public. [...] The IPCC report is extremely helpful, but not because people read it, but because it gives weight." – CC-3

"Normal people don't read scientific journals. So they read only popularized science by newspapers, or magazines, or whatever. The very important element is to train the journalists, to tell them how they should convey information." – CC-2

While the question about academic journals and non-academic media outlets was not intended as a request to compare their importance, the majority of climate change experts mentioned the irrelevance of scientific sources and the importance of news media sources. Also other questions, like general quality influences, were answered in regards to communication to the public, even if the question was not limited to it.

4.2. Climate Change Data Visualizations

An integral part of the interviews with participants from all three backgrounds (17) was the discussion of data visualizations as a means of communicating climate change topics. This section summarizes the main findings in regards to climate change data visualizations.

4.2.1. Communicating Data Visually Comes with Benefits

"If you don't use these [visualization] techniques, it's almost impossible to communicate it. [...] You cannot write a textbook about climate without using images and also without using data visualization." – VIS-2

Participants acknowledged the necessity and the benefits of visual communication. 11 participants across all three groups (5 CC, 3 SC, 3 VIS) stated that they would first look at the data visualization in a news article about climate change (if present and visibly placed) before reading the text. Eight participants (3 CC, 2 SC, 3 VIS) also think that common news sources like newspapers should make more use of data visualizations when communicating climate change topics.

"Data visualization here is key for people to raise awareness and to get the picture. I mean, there's this classical saying that if you can put things in text, that's nice. If you can put it in one graph way better." – CC-5

Participants' reasoning for the advantages of using data visualizations in this context can be summarized along the below lines:

- **Attention and engagement:** Data visualizations are said to do well in catching and keeping the user's attention (3 CC, 3 SC, 3 VIS).

  "And that's the great turning point in the recent years that visualization of information is the game changer to get the attention and awareness of the audience." – SC-2

- **Visual preference:** Participants (3 CC, 2 SC, 1 VIS) mentioned that people show a general preference toward visual formats.

  "There's such things in neuroscience or psychology that say that visual things are more attractive to the brain, and they support the processing of information." – SC-4

- **Possibilities to show data:** Data visualizations can also enable the creator to show high amounts and complex data (3 SC, 3 VIS).

  "You can show a lot of data. [...] You can compare different countries with each other in different circumstances. And also structural information, like what part of the world's industries are responsible for this and this fraction of the whole problem. Good visualizations also enable readers to find their own questions, their own interests. How's my country doing?" – VIS-4

- **Complexity reduction and understandability:** Participants (6 CC, 4 SC) argued that data visualizations can be used to reduce a topic's complexity and increase understandability for the readers.

  "Many people don't have this scientific knowledge to understand the wording in a sentence, perhaps, but you could simplify it and give it to them as a visual and then they would be able to understand and make use of the knowledge." – SC-5

Interviewees were also asked about the drawbacks of using data visualizations when communicating climate change topics. While several problems were mentioned that need to be considered when using data visualizations (which will be discussed in the following sections), these issues for the most part did not speak against the usage. 9 participants (2 CC, 3 SC, 4 VIS) expressed their concern about data visualizations that are used to mislead and manipulate the reader intentionally. However, this is also a problem when it comes to textual representations. According to the participants, a factor that could be considered as a real drawback of data visualizations compared to text is their lower accessibility for visually impaired persons (3).

"Another issue of visualization is, of course, that you can misuse it, you can make misleading visualizations, either by accident or on purpose. But that's not only a problem of visualization, in text you can also lie what you want and try to get away with that." – VIS-4

"I couldn't think of one. Well, for people which are maybe blind [...]. If you have a text reading program, you can read this. So for disabled people, yes, there's a drawback." – CC-5 (about the drawbacks of using data visualizations)

Benefits of communicating climate change through data visualizations were acknowledged by all expert groups. However, aspects of complexity reduction and understandability were only mentioned by climate change and science communication experts.

4.2.2. Quality Depends on the Purpose

"And sometimes I argue to students, there's not a good or a bad visualization. It really depends on the purpose you have. I can complain that a visualization is far too simple and doesn't show enough detail. Well, if you have three seconds to look at the picture, it's good if it's very simple, right?" – VIS-4

Solely exploiting the benefits of data visualizations by using more of them to communicate climate change to the public seems to be not enough. During the interviews 10 participants (4 CC, 4 SC, 2 VIS) stressed the importance of quality when it comes to data visualizations. Even to catch their first attention, some participants mentioned that they would be more likely to look at a well-done visualization compared to ordinary or badly designed graphics (4 SC). Likewise, the question whether news sources should make more or less use of data visualizations was also partly answered with respect to quality (2 SC).

"It really does depend on the visualization itself. Whether it's attractive, whether it looks understandable on the very first sight, you know, people's attention spans are very low, so is mine. The visualization would have to be very outstanding." – SC-4

While the quality of a data visualization is determined by a number of different aspects (see Section 4.3), it seems to be undisputed that creating high-quality data visualizations is not a trivial task. Without being excessively negligent, design choices might unintentionally result in ambiguous or misleading data visualizations (4) or finally readers misinterpreting the main message (5).

"I think the most important is ambiguity in the message, that it's very hard to create a graphic that is unambiguous in its message. Can be done, but requires work." – CC-1

11 participants (4 CC, 4 SC, 3 VIS) mentioned that the quality of data visualizations used in popular news sources highly depends on the publishing medium, with some high-quality newspapers creating excellent data visualizations and other less sophisticated media outlets showing a significant drop in quality also for their visualizations.

"You would probably need to differentiate very much on the news sources, because there are quality news sources and tabloids. [...] The higher the quality of the news outlets, the better the visualization." – SC-3

The assessment whether data visualizations are well-designed or not is also strongly related to the visualization's purpose, outlet, or audience. While a data visualization could be very appropriate for a scientific source, it can be a bad choice for a newspaper article, and the other way around. When presented with Figure 3.3, 7 participants (2 CC, 2 SC, 3 VIS) felt that the creator of this visualization did a good job in depicting the main message for the purpose of a newspaper visualization, while 8 participants (4 CC, 3 SC, 1 VIS) regarded the visualization as mediocre and 1 (VIS) participant as bad. Reasons for this assessment are discussed in Section 4.3. When asked about their personal preference in respect to the two example visualizations (Figure 3.3 in comparison to Figure 3.4), 8 participants (1 CC, 3 SC, 4 VIS) explained that their preference depends on the purpose of the visualization.

"There are things that are possible in a newspaper or on television that are just not possible in an IPCC report. That already tells that some decisions which are appropriate in one setting are wildly inappropriate in another." – CC-1

Without being directly asked about it, the importance of quality and the purpose of a visualization was mentioned by participants among all groups, with science communication experts stressing quality issues (in respect to their attention or the usage of data visualizations) most often.

4.2.3. We Need to Teach Data Visualization and Climate Change

> *"It's a technical issue and thus can be taught. And we don't do that. We don't appreciate that nearly enough [...], that it can [...] and should be taught"* – CC-1

Creating effective data visualizations is not easy, but can and should be taught according to the participants. While 4 participants think that there have been improvements in the last years when it comes to visualization contents in university education, the majority of participants (12) across all groups are convinced that current university curricula from various fields could be improved by adding visualization courses.

"It's not taught enough. For example, in the curriculas I'm teaching and I'm involved in the environmental sciences, [...] it's not taught at all, zero, nada, nothing." – CC-5

Not only creating data visualizations, but also consuming and interpreting them requires different kinds of background knowledge (14). 5 participants (1 CC, 1 SC, 3 VIS) mentioned the lack of visual data literacy among the public as a problem. Areas of education that should be emphasized to improve visual literacy include mathematics (5), visualization knowledge (5), as well as background knowledge about the data itself (1).

"One mistake we in the visualization community make is that we overestimate the visual literacy of people. And that's important to be aware of. It's interesting when we are at conferences, from people that are professional journalists or data journalists, [...] their upper limit, in complexity, is the scatterplot." – VIS-4

Background knowledge about the data might not be a given for a lot of people: one participant commented on the issue of education as one of the main climate change topics currently. A lack of education or socialization in regards to climate change was also mentioned as a reason for low ratings of understanding among the public (2). However, with climate change being an inherently complex topic, participants acknowledged that a deep understanding among the public might not be a realistic goal (1) and it is more the trust in science that gets lay people to acknowledge the urgency of climate change (1).

"We should start from the kindergarten throughout the whole educational path, to build into the curricula, at whatever level, at whatever discipline, also sustainability related issues. [...] Most of people have not been socialized in a context where these issues were important. And becoming aware [...] at a later stage in life is more complicated." – CC-2

"The whole concept of climate change is not a very simple one. [...] As long as you're not a scientist yourself, you pretty much have to, I would really put it that way, you have to believe in it, you have to trust science, which is very close to believing in something, because you cannot reproduce that knowledge." – SC-4

The need for more data visualization education was acknowledged by a majority of the participants over all expert groups.

4.3. Implications for Creating Effective Climate Change Data Visualizations

Participants shared their opinions on what makes a high-quality data visualization for them and made recommendations on how to create effective data visualizations about climate change. Implications presented in this section, were drawn from interviewees' explicit general recommendations, or from comments in respect to the example visualizations.

4.3.1. Embrace the Process

> *"What we should try to push for is not just more datavis in general, it's a new way of designing them, how we design data visualization, or we co-design data visualization."* – SC-6

Participants claimed that the design process of a data visualization has a substantial influence on the resulting visualization quality: mentioned factors included co-design (3), iterative design (2), as well as framework conditions like time and funding (2) and visualization expertise (2). While the communication between domain and visualization experts was also named as a challenge, an effective iterative co-design process was described as the collaboration between climate change scientists and visualization experts that starts with the purpose of a visualization and passes through several design iterations, including user testing (2).

"Always really difficult [...] is the communication between those persons who know data, persons who know the area, for example climate change, and those who can really do excellent visualizations." – SC-1

"But overall, I think we can overcome all these problems, if we design in the right way, if we co-design. And if we have a human-centered approach, meaning that you co-design with the scientists to make sure that you have a very clear understanding as a designer." – SC-6 (about difficulties people might have when interpreting data visualizations)

The process of designing effective data visualizations about climate change was not explicitly asked for in the interview schedule. However, participants from all three expert groups mentioned factors how a successful design process might look like.

4.3.2. Embrace the Audience

> *"Embrace the audience in the design process to make sure that you understand how they interpret the information."* – SC-6

An iterative design process (1 CC, 1 SC) was also mentioned in the context of user testing and creating data visualizations in a way that makes them understandable for their intended target audience: adapting climate change data visuals to the knowledge

and needs of the users was named by 5 interviewees (2 SC, 3 VIS) as an aspect of how to influence the quality of data visualizations. Furthermore, those with a science communication or a data visualization background also named the optimization in respect to the used publication channel as an important aspect for creating high-quality data visualizations (3 SC, 2 VIS).

"But it's hard. I'm not the typical target audience. Right? Or I'm not representative, I guess. So to me, that would be a very clear way to visualize it." – VIS-3 (about Figure 3.3)

Even though the complexity of the topic of climate change was widely acknowledged among climate change experts, the adaption of climate change visualizations to the target audience's needs was mainly mentioned by science communication and data visualization experts as a way to influence the quality of a data visualization.

4.3.3. Make it Simple, but Transparent

"Being simple on complex issues is one of the most complex tasks we have."
– CC-2

Independent of the example visualizations that were shown to the interviewees, this question was posed to all participants: "Would you say it is rather easy or difficult for people to interpret visualizations about climate change correctly?". While 13 participants (4 CC, 6 SC, 3 VIS) claimed that it would be difficult, especially for people with no prior knowledge in climate change or data visualization, 2 interviewees thought that it should be easy for anyone.

"For a long time, I thought it's easy and everybody would understand that. [...] Particularly now in the Corona age I have learned that this is really not the case. So people have much more problems to read such images, or data visualizations, than I thought." – VIS-2

In this context, participants among all expert groups have also mentioned that peoples' ability to interpret data visualizations about climate change heavily depends on the visualization design (5), whereby some speak in favor of designing climate change data visualizations in a way that makes them accessible to anybody. In addition, 7 participants (3 CC, 3 SC, 1 VIS) named simplicity and complexity reduction as key factors in creating effective data visualizations.

"If the visualization is done very good, it should be super easy to understand it. And that's the problem with most visualizations, that they're not doing this job. So most visualizations are still too complex. [...] I would say, you need to reach the average consumer and you need to include this disadvantaged part of the society also." – CC-5

The opinions about the understandability of Figure 3.3 were quite diverse. While 9 participants among all expert groups claimed that it should be easy for people without prior knowledge in climate change or data visualization to interpret this particular

visualization, 6 participants thought this would be difficult. Some interviewees mentioned that the ability to interpret Figure 3.3 highly depends on the person reading the graph (3 SC, 2 VIS). The simplifications made in Figure 3.3 compared to Figure 3.4 were mentioned as positive criticism by 3 participants, and 4 thought that Figure 3.3 was still too complicated for a news article.

"It is still this science graph style, with y axis, x axis and so on. This would not be the type of data visualization I would envision for the broader public. It is too complex." – CC-5 (about Figure 3.3)

"This is a graph that I can read and also every researcher can understand. But for laymen, it's just too abstract." – VIS-2 (about Figure 3.3)

Throughout the interviews, the issue of simplification vs. accuracy was discussed by the participants. While 4 interviewees pointed out that over-simplification of contents can be problematic, simplification was also named as an important quality factor for the creation of understandable data visualizations (3 CC, 3 SC, 1 VIS). Factors that support this need for simplification include the complexity of climate change (2 CC, 2 SC) and missing time and involvement on the reader's side (4).

"The depth level into which you can dive it's just very limited. [...] The risk you run, if you insist on scientific rigor, say in that BBC figure, is that you might lose your audience altogether. And then you're not conveying the depth of your message either. If no-one is listening, what's the point of having the best graphic, or the more accurate graphic? [...] I could not easily criticize someone for simplifying unless simplification eliminates the heart of the matter." – CC-1

"Put things as clear and as simple as possible. I think the same thing with data visualization, there is no such thing like oversimplification. Put the thing simple." – CC-5

"Science communication always means narrowing things down, always means simplifying complex data. [...] Still, you need to put some effort in being correct and not being shady about numbers and stuff." – SC-4

The need for simplification was an apparent theme among all expert groups, with science communication experts being more set on maintaining scientific accuracy than experts from other groups.

4.3.4. Make it Relatable

"You really have to make sure that people can relate with whatever you communicate toward them. Which is definitely difficult when it comes to climate change, because it's a very abstract thing, still." – SC-4

Participants have also emphasized that relatability to the contents of a data visualization plays a big role in getting and keeping the readers' attention. While 3 participants (1 SC, 2 VIS) have mentioned creating relatable climate change data visualizations as a general recommendation, 5 participants (1 SC, 4 VIS) criticized Figure 3.3 for not showing any consequences that the readers can relate to. Visualization types were mentioned as a means to increase relatability (4), for example by choosing maps to show the consequences for specific regions.

"It's about relatability. I think you could quite easily visualize this, using a map instead of this graph, which could be much more relatable, I would say, because people can place themselves on a map but cannot really place themselves, or the place they live in, in that graph." – SC-4 (about Figure 3.3)

Particularly data visualization experts have stressed the importance of depicting contents, which are relatable for the intended target audience, as a means to capture and keep the readers' attention.

4.3.5. Tell a Clear Story

> *"And if you don't know what the intent is, I mean, all hope is lost, there's no way you can ever do a good graphic, except by complete accident."* – CC-1

As factors that positively influence the quality of climate change data visualizations, participants mentioned the definition of a clear main message or intent of a visualization (1 CC, 2 SC, 2 VIS), story telling techniques (1 SC, 3 VIS), as well as the effective combination of visualization and accompanying text (3 CC, 2 SC, 2 VIS).

"Just showing data doesn't work, you have to annotate them and make clear what it is about, tell a story with them. If it's more subtle and complex, then I expect also text explaining different points of views or things that interact. [...] It's often a good idea to have a good mix of text and visualizations." – VIS-4

It is not only important that a distinct story is told with the visualization, but also that it is told in a way that makes it understandable for the intended audience. In regard to Figure 3.3, opinions were divided: while some participants have spoken in favor of the title (1 SC, 2 VIS) and the annotations (1 CC, 3 VIS), 7 participants among all expert groups criticized that the used wording is too complicated for a newspaper source and 6 participants expressed that they would have liked annotations for the lines that are just summarized as "Different possible scenarios". Furthermore, 4 interviewees voiced that according to their opinion the main message of this specific visualization is not clear.

"It's too complex wording: 'different possible scenarios', to start with, 'observed temperatures', 'future based on sustainability'. Nice for us scientists, for the broader public: way too complicated." – CC-5 (about Figure 3.3)

This suggests that data visualization creators should aim at conveying a clear message, which should be adjusted to the audience's prior knowledge to ensure understandability.

4.3.6. Make it Attractive

> *"If you're communicating to the general public, there's this stuff you can do. [...] To actually add graphical depictions around, to add more color, to add memorable context. [...] It attracts people in the first place. And that's what you want, right? You want them to engage with the data."* – VIS-1

Besides contents, also aspects of good design practices as well as aesthetics matter: while the amount of information should not overload the visualization (2), contents should be presented in a clear manner (2). 3 participants (1 CC, 2 VIS) mentioned guiding user perception through positioning and highlighting of important information. Info-graphics were mentioned by science communication as well as data visualization experts as a way to engage the general public in complex topics like climate change (2 SC, 2 VIS): by using color, pictures or icons, creators of data visualizations could gain the attention of readers who are not particularly interested in climate change.

"If you have images, which create some emotion, [...] this would be much more helpful. Because this creates interest and when they are interested they also invest more time. [...] If you want to maximize your impact, one has to start with very very simple things, very basic visualizations, very different from what we do in science." – VIS-2

Such aspects were also mentioned in regard to the example visualizations: 2 science communication experts criticized that Figure 3.3 is missing pictures or icons that would make it more appealing for the general public. Some interviewees also expressed that Figure 3.3 appears to be cluttered, suggesting a reduction of text (7) or different positioning of the annotations (2). Finally, participants had different opinions concerning the line coloring in Figure 3.3. While 7 participants among all expert groups felt that the colors seem random and would have liked some sort of blue-to-red color scale, 3 data visualization experts spoke in favor of the categorical colors, as they are easily distinguishable.

"From a visualization point of view the colors – totally random. Strange that they use purple twice, light and dark purple. I expect some ordering here. Yeah, if I look carefully, then the sustainable one is greenish. But the yellow orange ones, this is also quite a happy color." – VIS-4

Principles of good design and aesthetics were mentioned by participants from all three expert groups. Science communication and data visualization experts spoke in favor of using info-graphics as an effective tool to communicate climate change to lay audiences.

4.3.7. Adapt Uncertainty Representations to the Audience

"To be academically correct, you would need to include the confidence intervals. However, we do know that citizens have a huge issue with interpreting and understanding confidence intervals." – SC-3

Opinions whether to include or exclude uncertainty in climate change data visualizations for the public varied among participants. For Figure 3.3 as a news media representation, 8 participants (1 CC, 2 SC, 5 VIS) regarded it as positive, and 3 participants (1 CC, 2 SC) as negative that the uncertainty ranges from the original visualization were not shown in the BBC's version. Independent of the example visualizations, 5 participants (3 CC, 2 SC) spoke in favor of showing uncertainty in data visualizations in order to not loose the reader's trust.

"You have to communicate uncertainty, but you have to communicate what it means. That's very hard, it's also like weather prediction uncertainty is also very hard to communicate. But I feel like if there is uncertainty, we need to communicate it openly and transparent. [...]. If you don't communicate uncertainty, we will later be accused of kind of hiding uncertainty." – CC-3

Uncertainty plays a big part in predictions and simulations about the consequences of climate change, but it is not an easy concept: 8 participants (4 CC, 2 SC, 2 VIS) mentioned that understanding and communicating uncertainties about climate change (apart from data visualizations) can be challenging. 5 participants (2 CC, 3 VIS) named visualizing uncertainty as one of the problems when creating data visualizations and another 6 participants among all expert groups felt that uncertainties are difficult for lay users to understand. A possible solution could lie in emphasizing those issues in the school education.

"If the target audience is a scientist, then definitely it's important, what's the uncertainty [...]. But I don't see an added benefit of putting that burden of uncertainty onto the reader because it doesn't make a huge difference for the main message." – VIS-3

"I would say in future it should be normal to have this uncertainty included, but then you have to teach this in school that people are educated to learn or to handle the question, what is a prediction and what is the confidence interval and all these things. I mean, nobody knows this in Austria." – SC-1

While climate change and science communication experts were more torn about the question of including or excluding uncertainty for communicating climate change to the public, data visualization experts spoke in favor of excluding the uncertainty for visualizations for lay audiences unless it would eliminate the heart of the matter.

4.3.8. Make it Interactive, Only if it Fits the Users' Needs

> *"We always start to comment the core messages and will the users really need [the interactivity]. Interactivity [...] has to be a consequence of those needs. It's not just something that we decide to do because it's cool."* – SC-6

Participants stated that especially for climate change data, interactive visualization techniques can be a powerful way to engage users in the data (2). While interactive data visualization can be suitable for specific purposes (3), like showing historical data (1), one participant argued that creators of data visualizations should only make use of interactivity components, if there's an added benefit for the user. Mentioned benefits and drawbacks of interactive data visualizations include:

- **Increased engagement:** Participants (8) among all expert groups named increased engagement of users as a benefit of using interactive visualization techniques, as interactive elements would give users the possibility to explore the data by "playing around".
- **Increased relatedness:** According to 4 participants (1 CC, 3 VIS), interactive data visualizations can be more relatable than their static counterparts, as users can pose their own questions.
- **Allows for high amounts of data:** Another benefit of interactivity that was mentioned lies in the opportunity to depict larger data sets, compared to static visualizations (3).
- **Expensive to realize:** Interviewees (3) acknowledged that interactive data visualizations usually take more effort to realize, both in terms of time and costs.
- **Limited accessibility:** 7 participants (1 CC, 2 SC, 4 VIS) pointed out that interactive tools are only accessible to younger generations that have the means and knowledge to use them.
- **Limited engagement:** Despite their potential to increase engagement, 7 participants (4 SC, 3 VIS) also worried that after trying out some functionalities, interest among users can drop leading them to not fully explore the potentials of the tool.

> *"I think it is limited to a certain part of the public, those who are more comfortable with interactive communication means."* – CC-4

Results indicate that increased engagement can be a benefit of interactivity, but it is not a given. Science communication and data visualization experts pointed out that interactive data visualizations often fail to keep user attention beyond the initial interest.

5. Discussion and Conclusion

Visual climate change communication has been studied before (Section 2), but studies testing the understandability of climate change data visualizations and communication handbooks mostly focus on visualizations published by the IPCC (e.g. [6, 13, 23, 24, 46]). While IPCC visuals have been criticized in the past [24], recent publications have evoked positive criticism for their visualizations by public comments [18, 27] as well as by our interview participants (CC-1). With the IPCC being the major voice of climate science, studies about the visual communication in IPCC publications are indisputably of great importance. However, our results show that while the IPCC "gives weight" (CC-3), the general public tends to obtain information through different channels. Participants have stressed the importance of news media for informing the public about climate change. The interviews suggest that there is room for improvement when it comes to climate change data visualizations in common news sources, but also that it is crucial to develop guidelines on how to translate scientific contents into visual formats for the public.

5.1. It's All about the Audience

Throughout our interviews, the importance of the audience was a common theme: questions about visualization quality or design choices were commonly answered by "it depends on the audience" or "it depends on the purpose". Previous research has shown that the ability to understand climate change data visuals is influenced by the readers' background: In their 2021 empirical testing of visualizations depicting climate change mitigation scenarios, Xexakis and Trutnevyte [79] conducted online surveys in Germany, Poland, and France focusing on the citizens' interpretation of those scenarios. The authors found that the respondents' background including demographics, numeracy, graph literacy and prior beliefs impact their reading accuracy of the presented visualizations. More precisely, respondents with a higher education level and advanced numeracy and graph literacy showed increased reading accuracy in all countries, while respondents of higher age performed considerably worse. Respondents with prior belief systems and knowledge about climate change mitigation scenarios had a higher reading accuracy, if their prior beliefs matched the information depicted by the visualization. The authors emphasize the importance of designing visualizations in a way that makes them accessible for the target audience. The influence of readers' prior perceptions about climate change was also found to influence their interpretation of climate change data visualizations in other studies (see [1]). Hence, diverse levels of prior knowledge and other conditions like demographics or prior beliefs among different audiences should be taken into account when creating data visualizations about climate change (e.g. [6, 19, 23]).

5.1.1. "Why Should I Care?" – Ensuring Interest and Relatability

The interviews indicate that public "awareness is very much related to the connection with particular events" (CC-4), with recent occurrences of floods, storms and fires making climate change more tangible for a lot of people. But what do we need to know about the audience to make data visualizations interesting and relatable? We discuss three starting points that are important to consider about the audience to create climate change data visualizations that are interesting and attractive for the readers as well as to which the readers can relate to: the usage of media channels, the reader's willingness to spend time on a visualization, and the reader's interests and concerns.

Usage of media channels. As a first step toward designing effective data visualizations for their intended audience, our findings suggest to have a closer look at the purpose and channel in which a data visualization should appear. While different channels impose different requirements (e.g. more simplification needed for TV or social media channels, as the time frame in which users can/will look at a data visual is shorter), also online vs. print and mobile vs. desktop news consumption influences which visualization design is most suitable.

Willingness to spend time on a visualization. The willingness to look at a visualization is also influenced by the visualization design itself, as our findings suggest. Factors like visualization type, complexity, clarity of the main message, and design details can be used to make a visualization attractive for a specific audience. These points have also been emphasized by prior work, e.g. by Harold et al. [23] who give recommendations to IPCC researchers for creating effective data visuals. Our participants mentioned that infographics can be used as a tool to catch the public's interest for climate change issues. While there is mixed evidence about their effectiveness in terms of users memorizing the shown data, previous research has shown that infographics can increase user engagement and aesthetic value, as well as memory of the visualization [16]. However, it is advisable to also consider how specific visualization types are perceived by the readers and which effects they have on aspects like credibility and readability. McMahon [47] compared classical IPCC images to another category of visualizations, namely some open sourced infographics. Results of a group-administered study showed that the type of visualization had a significant impact on how non-expert viewers perceive the image and on their ability to associate relevant words with it. In fact, visuals that were published in the IPCC's Summary for Policymakers had a stronger positive impact on readers' confidence than infographics. While the accessibility of infographics is undisputed, this study suggests that classic scientific graphics like they are used in IPCC reports are associated with higher credibility.

Interests and concerns. A third factor in motivating the users to engage with a visual lies in the relatability of the contents. Adapting contents toward information that is interesting to the users, using appropriate visualization types, and telling a story that readers can relate to are factors how visualization designers can gain the public's interest.

Corner et al. [6] introduce principles to use in public engagement, which read: "Connect with what matters to your audience" or "Tell a human story". While our findings suggest that establishing an emotional connectedness between users' concerns and shown data can increase interest, the role of affective communication, incorporating emotional elements into the presentation of data and risk has been researched before as a way to foster engagement [36, 38].

5.1.2. "What Does that Mean?" – Ensuring Understandability

What do we need to know about the audience to make data visualizations understandable? The interviews and previous literature have shown that catching the readers' interest is not enough: in order to foster understanding, data visualizations have to be created in a way that meets the readers' needs. We derive three main considerations about the audience to create understandable data visualizations: knowledge and beliefs about climate change, familiarity with visualization types, and knowledge about uncertainty and statistics.

Knowledge and beliefs about climate change. Our findings indicate that the complexity of climate change as a topic as well as the urgency for action single out this issue from other science communication fields. Identifying the audience's prior knowledge and beliefs about climate change helps visualization designers to determine an appropriate depth of the contents as well as to select understandable terminology. While the reduction of complexity for climate change visuals for the public was recommended previously [24], also the usage of simple captions and known terminology was shown to have a positive impact on readers' understanding [35]. As mentioned before, the influence of readers' prior beliefs about climate change was found to influence their interpretation of climate change data visualizations in previous research [1, 79].

Familiarity with visualization types. In addition to knowledge about climate change, our findings suggest that the audience's familiarity with visualization types plays an important role in communicating to the public. Identifying visualization types that the audience is confident about can help climate change visualization designers to increase the understandability among the readers. This is in accordance with previous work, which found that the type of visualization has a significant impact on how non-expert viewers perceive visuals [47] and that readers prefer graph formats with which they are most confident (e.g. [16, 39]). In their online survey with adaptation practitioners in Germany and the UK, Lorenz et al. [39] investigated the respondents' comprehension of climate change visuals, as well as their preference for a specific visualization format. Results show that the respondents preferred graph formats with which they are most confident independently of the fact if they actually understand them best. While interactive climate change visualizations are known to be beneficial in aspects like drawing and maintaining the users' interest [50], we need to consider that not everyone has the ability or the means to use them.

Knowledge about uncertainty and statistics. Our results indicate that the decision to include or exclude details about the associated uncertainty in simulations or predictions strongly depends on the readers' previous knowledge about uncertainty and statistics. The difficulty of understanding uncertainty in public climate change communication was also acknowledged previously, with one principle for IPCC authors to use in public engagement reading "Lead with what you know" [6]. While different aspects of showing uncertainty in climate change visuals have been studied (e.g. [7, 35, 64]), we recommend to adapt the uncertainty in a visual to the readers' prior knowledge and explain important aspects in the accompanying text. Especially when thinking about non-expert audiences the potential diversity of readers stands out. However, it might be an incentive to focus on adaptable visualizations (in an online context) or visual storytelling that builds up complexity step by step, allowing people to stop engaging when they see fit – as can be seen in the work of some practitioners.

5.2. Tension between Simplicity and Accuracy

Finding methods "to convey information to a broader public in a way that it is simple, but [...] scientifically sound [...] is one of the biggest challenges" (CC-2). With the complexity of climate change as a topic being uncontested, the need for complexity reduction in visuals has been claimed previously (e.g. [24]) as well as by our interviewees. While IPCC authors were found to be aware about the level of comprehension difficulty in their visuals [25], simplifying content while prevailing scientific accuracy is not trivial. Our findings suggest that simplifications are important and necessary to meet the needs of diverse audiences, but visualization designers have to be transparent about them in order to avoid oversimplifying contents and potentially loosing the reader's trust. In this regard, text can play an important role: when a data visualization excludes some information for the sake of simplicity, interviewees suggested that an accompanying text could bridge the gap between simplification and accuracy, e.g. by making the reader aware of details that are not depicted in the visual. How do we address both the need for scientific accuracy as well as the needs of the users of a climate change data visualization? Literature as well as our findings indicate that a highly iterative, user-centered co-design process, including domain and visualization experts as well as user-testing is the way forward [19, 49]. User-centered design approaches could be used to "ensure the creation of tailored visualisations" [19, p. 315]. While such approaches have been in place for IPCC visualizations [49] and included in their recommendations [23], our findings suggest that these practices might also be beneficial for designing climate change data visualizations for common news sources.

5.3. A Complex, Urgent, and Inconvenient Message

In many cases our results show parallels to general principles of science communication (e.g. [15]) and principles of visual data communication (e.g. [16]). However, what is unique about climate change is the complexity of the data on the one hand, and the urgency to take action on the other hand. Our results suggest, that a deep understanding among the public concerning climate change issues might not be a realistic goal: "we will never be able to convey this complexity to everybody" (CC-2). Rather, it is important to establish a trust in science (e.g. [4]), and to effectively convey the most important messages about climate change to the public, for example by using data visualizations. In this context, van der Linden et al. [72] found that the scientific consensus about climate change topics "is most effectively communicated as a short, simple message that is easy to comprehend and remember" [72, p. 255]. Despite all efforts to communicate the scientific evidence in an effective and understandable way, acknowledging the need for action might also be hindered by its inconvenient implications. If we "really want to change something, it will hurt" (VIS-4), which applies to private persons (e.g. way of living), companies (e.g. investing in climate friendly alternatives), as well as to politicians (e.g. chances for getting elected). Finally, "the theory of path dependency shows that it is easier to [continue] as we did before than changing paths" (CC-2). Hence, also cognitive biases, like the status quo bias (e.g. [58, 65]), could restrain us from giving "climate action the high priority it is due" [3, p. 3].

5.4. Limitations and Future Work

As with every study our findings have to be understood within the limits of the study design. While the minimum sample size, at which data saturation is normally reached, was exceeded [17, 21], the interviews are still limited in number and in respect to the included fields of expertise. Furthermore, our sample shows a clear focus on European and more specifically on [country name removed for review] participants, with some of them making their arguments for local circumstances. As we opted for seeking expert opinions, we cannot make inferences on how one or the other design choice would actually work for non-expert users. Finally, our questions were aimed at opinions about broader themes, instead of details about sub-themes, hence, results might (in part) not be specific to climate change data visualizations, but apply to data visualization and science communication in general.

Future research could address some of the remaining open questions regarding climate change communication to the public facilitated by data visualizations. While it would be interesting to see how data visualizations about climate change are created and used in news media, their understandability could be investigated with lay users who are a more representative sample for the general public. It would also be beneficial to test different design options (e.g. including/excluding uncertainty or other details) and how this affects readers' understanding. In addition, it could be investigated how different forms of climate change data visualizations perform in catching the readers' interest.

Those approaches could take an important part in informing how climate change can be communicated to lay audiences and how journalists can translate scientific contents into effective visualizations for the public.

5.5. Conclusion

The science behind climate change is unequivocal: Climate change is human-caused, we are experiencing various consequences already today and in order to avoid more devastating effects we need to act now. Hence, communicating climate change facts not only to decision makers but also to the public is one of the big challenges of our time in order to raise awareness and understanding and finally to facilitate action. With climate change communication experiencing a shift toward visualization, visuals are used by a variety of stakeholders to achieve a number of different goals. However, with climate change data being inherently complex, visualizing data in a way that makes it accessible for different audiences while still maintaining scientific accuracy is a challenge not only climate scientists are facing. On the basis of expert interviews, we derived implications for creating more effective visualizations, particularly in news media sources geared toward lay audiences.

While expert opinions from different fields of expertise are indisputably an important starting point when it comes to (visual) climate change communication, our results suggest that more emphasis should be put on data visualizations for the public. However, in this study design we did not conduct any interviews or tests with lay audiences, as we specifically aimed for expert opinions on various aspects of visual climate change communication. Thereby, our goal was to investigate what different groups of potential climate change visualization creators (climate change, science communication, and data visualization experts) regarded as important aspects when communicating climate change and consequently to identify prevailing themes for future work. An expansion of this qualitative research approach to lay audiences would provide further important insights. Further weaknesses of the study lie in the broadness of the questions and hence the difficulty of a clear distinction between climate change specific and general data visualization aspects. To address these weaknesses, further steps of this research will be to extend and adapt the interviews to a diverse set of lay people and to follow up with co-design workshops with the aim of designing climate change visualizations with and for a broader audience. Furthermore, an analysis of the current state of climate change data visualizations in popular news/social media sources and testing different designs that are commonly found in news sources with lay audiences in terms of their understandability would contribute to the current knowledge of visual data communication in the field of climate change.

Bibliography

[1] A. G. Ballantyne, V. Wibeck, and T.-S. Neset. Images of climate change – a pilot study of young people's perceptions of ICT-based climate visualization. *Climatic Change*, 134(1):73–85, Jan. 2016. doi: 10.1007/s10584-015-1533-9

[2] G. Beattie and L. McGuire. See no evil? Only implicit attitudes predict unconscious eye movements towards images of climate change. *Semiotica*, 2012(192):315–339, Jan. 2012. doi: 10.1515/sem-2012-0066

[3] S. Boehm, K. Lebling, K. Levin, H. Fekete, J. Jaeger, R. Waite, A. Nilsson, J. Thwaites, R. Wilson, A. Geiges, C. Schumer, M. Dennis, K. Ross, S. Castellanos, R. Shrestha, N. Singh, M. Weisse, L. Lazer, L. Jeffery, L. Freehafer, E. Gray, L. Zhou, M. Gidden, and M. Galvin. State of Climate Action 2021: Systems transformations required to limit global warming to 1.5° C. *Washington, DC: World Resources Institute*, Oct. 2021. doi: 10.46830/wrirpt.21.00048

[4] P. R. Brewer and B. L. Ley. Whose science do you believe? Explaining trust in sources of scientific information about the environment. *Science Communication*, 35(1):115–137, Feb. 2013. doi: 10.1177/1075547012441691

[5] D. A. Chapman, A. Corner, R. Webster, and E. M. Markowitz. Climate visuals: A mixed methods investigation of public perceptions of climate images in three countries. *Global Environmental Change*, 41:172–182, Nov. 2016. doi: 10.1016/j.gloenvcha.2016.10.003

[6] A. Corner, C. Shaw, and J. Clarke. Principles for effective communication and public engagement on climate change: A handbook for IPCC authors, Jan. 2018. Oxford: Climate Outreach.

[7] J. D. Daron, S. Lorenz, P. Wolski, R. C. Blamey, and C. Jack. Interpreting climate data visualisations to inform adaptation decisions. *Climate Risk Management*, 10:17–26, July 2015. doi: 10.1016/j.crm.2015.06.007

[8] R. Duan, B. Takahashi, and A. Zwickle. Abstract or concrete? The effect of climate change images on people's estimation of egocentric psychological distance. *Public Understanding of Science*, 28:828–844, July 2019. doi: 10.1177/0963662519865982

[9] R. Duan, B. Takahashi, and A. Zwickle. How effective are concrete and abstract climate change images? The moderating role of construal level in climate change visual communication. *Science Communication*, 43(3):358–387, Apr. 2021. doi: 10.1177/10755470211008192

[10] K. Dudman and S. de Wit. An IPCC that listens: Introducing reciprocity to climate change communication. *Climatic Change*, 168(1):2, Sept. 2021. doi: 10.1007/s10584-021-03186-x

[11] P. Eavis and C. Krauss. What's really behind corporate promises on climate change?, Feb. 2021. https://www.nytimes.com/2021/02/22/business/energy-environment/corporations-climate-change.html Accessed on: 11 November 2022.

[12] L. Feldman and P. S. Hart. Is there any hope? How climate change news imagery and text influence audience emotions and support for climate mitigation policies. *Risk Analysis*, 38(3):585–602, Mar. 2018. doi: 10.1111/risa.12868

[13] H. Fischer, S. Schütte, A. Depoux, D. Amelung, and R. Sauerborn. How well do COP22 attendees understand graphs on climate change health impacts from the Fifth IPCC Assessment Report? *International Journal of Environmental Research and Public Health*, 15(5):875, May 2018. doi: 10.3390/ijerph15050875

[14] H. Fischer, K. L. van den Broek, K. Ramisch, and Y. Okan. When IPCC graphs can foster or bias understanding: evidence among decision-makers from governmental and non-governmental institutions. *Environmental research letters*, 15(11), 2020. doi: 10.1088/1748-9326/abbc3c

[15] B. Fischhoff. The sciences of science communication. *Proceedings of the National Academy of Sciences*, 110(supplement_3):14033–14039, Aug. 2013. doi: 10.1073/pnas.1213273110

[16] S. L. Franconeri, L. M. Padilla, P. Shah, J. M. Zacks, and J. Hullman. The science of visual data communication: What works. *Psychological Science in the Public Interest*, 22(3):110–161, Dec. 2021. doi: 10.1177/15291006211051956

[17] R. Galvin. How many interviews are enough? Do qualitative interviews in building energy consumption research produce reliable knowledge? *Journal of Building Engineering*, 1, Mar. 2015. doi: 10.1016/j.jobe.2014.12.001

[18] T. Gaulkin. "Why the bad news in the IPCC report is good news for visual learners." Thebulletin.org. `https://thebulletin.org/2021/08/why-the-bad-news-in-the-ipcc-report-is-good-news-for-visual-learners/` (accessed Mar. 29, 2022).

[19] S. Grainger, F. Mao, and W. Buytaert. Environmental data visualisation for non-scientific contexts: Literature review and design framework. *Environmental Modelling & Software*, 85:299–318, Nov. 2016. doi: 10.1016/j.envsoft.2016.09.004

[20] Guardian. "As a verdict on the climate crimes of humanity, the new Intergovernmental Panel on Climate Change report could not be clearer: we're guilty as hell." Instagram.com/guardian/. `https://www.instagram.com/p/CSXHuKIqCs1/` (accessed Mar. 29, 2022).

[21] G. Guest, A. Bunce, and L. Johnson. How many interviews are enough?: An experiment with data saturation and variability. *Field Methods*, 18(1):59–82, Feb. 2006. doi: 10.1177/1525822X05279903

[22] A. Hansen and D. Machin. Visually branding the environment: Climate change as a marketing opportunity. *Discourse Studies*, 10(6):777–794, Dec. 2008. doi: 10.1177/1461445608098200

[23] J. Harold, I. Lorenzoni, K. Coventry, and A. Minns. Enhancing the accessibility of climate change data visuals: Recommendations to the IPCC and guidance for researchers. Oct. 2017.

[24] J. Harold, I. Lorenzoni, T. F. Shipley, and K. R. Coventry. Cognitive and psychological science insights to improve climate change data visualization. *Nature Climate Change*, 6(12):1080–1089, Dec. 2016. doi: 10.1038/nclimate3162

[25] J. Harold, I. Lorenzoni, T. F. Shipley, and K. R. Coventry. Communication of IPCC visuals: IPCC authors' views and assessments of visual complexity. *Climatic Change*, 158(2):255–270, Jan. 2020. doi: 10.1007/s10584-019-02537-z

[26] P. S. Hart and L. Feldman. The impact of climate change-related imagery and text on public opinion and behavior change. *Science Communication*, 38(4):415–441, Aug. 2016. doi: 10.1177/1075547016655357

[27] E. Hawkins. "IPCC SPM Figures." Climate Lab Book. `https://www.climate-lab-book.ac.uk/2021/ipcc-spm-figures/` (accessed Mar. 29, 2022).

[28] B. W. Head. Wicked problems in public policy. *Public policy*, 3(2):101–118, Jan. 2008.

[29] J. E. Hopke and L. E. Hestres. Visualizing the Paris Climate Talks on Twitter: Media and climate stakeholder visual social media during COP21. *Social Media + Society*, 4(3), July 2018. doi: 10.1177/2056305118782687

[30] IPCC. "A new assessment cycle, a new visual identity." IPCC.ch. `https://wg1.ipcc.ch/sites/default/files/documents/ipcc_visual-identity_guidelines.pdf` (accessed Mar. 29, 2022).

[31] IPCC. "About the IPCC." IPCC.ch. `https://www.ipcc.ch/about/` (accessed Mar. 29, 2022).

[32] IPCC. Summary for Policymakers. In V. MassonDelmotte, P. Zhai, A. Pirani, M. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. Matthews, T. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou, eds., *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2021.

[33] J. Johansson, T.-S. S. Neset, and B.-O. Linnèr. Evaluating climate visualization: An information visualization approach. In E. Banissi, S. Bertschi, R. A. Burkhard, J. Counsell, M. Dastbaz, M. J. Eppler, C. Forsell, G. G. Grinstein, J. Johansson, M. Jern, F. Khosrowshahi, F. T. Marchese, C. Maple, R. Laing, U. Cvek, M. Trutschl, M. Sarfraz, L. J. Stuart, A. Ursyn, and T. G. Wyeld, eds., *14th International Conference on Information Visualisation, IV 2010, 26-29 July 2010, London, UK*, pp. 156–161. IEEE Computer Society, 2010. doi: 10.1109/IV.2010.32

[34] S. Joslyn and R. Demnitz. Explaining how long CO2 stays in the atmosphere: Does it change attitudes toward climate change? *Journal of Experimental Psychology: Applied*, 27(3):473–484, Sept. 2021. doi: 10.1037/xap0000347

[35] A. Kause, W. Bruine de Bruin, F. Fung, A. Taylor, and J. Lowe. Visualizations of projected rainfall change in the united kingdom: An interview study about user perceptions. *Sustainability*, 12, Apr. 2020. doi: 10.3390/su12072955

[36] H. Kennedy and R. L. Hill. The feeling of numbers: Emotions in everyday engagements with data and their visualisation. *Sociology*, 52(4):830–848, Aug. 2018. doi: 10.1177/0038038516674675

[37] E. Koptyug. "Number of online and mobile visits on news portals in Germany in February 2022". Statista.com. `https://www.statista.com/statistics/442988/most-visited-news-websites-germany/` (accessed Mar. 29, 2022).

[38] A. Leiserowitz. Climate change risk perception and policy preferences: The role of affect, imagery, and values. *Climatic Change*, 77(1):45–72, July 2006. doi: 10.1007/s10584-006-9059-9

[39] S. Lorenz, S. Dessai, P. M. Forster, and J. Paavola. Tailoring the visual communication of climate projections for local adaptation practitioners in Germany and the UK. *Philosophical Transactions of the Royal Society A*, 373:20140457, Nov. 2015. doi: 10.1098/rsta.2014.0457

[40] T. Lowe, K. Brown, S. Dessai, M. de França Doria, K. Haynes, and K. Vincent. Does tomorrow ever come? Disaster narrative and public perceptions of climate change. *Public Understanding of Science*, 15(4):435–457, Oct. 2006. doi: 10.1177/0963662506063796

[41] A. Majid. "New York Times was the UK's fastest growing online news brand in February: Top 50 digital news ranking". Pressgazette.co.uk. `https://www.pressgazette.co.uk/most-popular-websites-news-uk-monthly/` (accessed Mar. 29, 2022).

[42] A. Majid. "Top 50 news sites in the US in January: Growth continues at Sun's US edition". Pressgazette.co.uk. `https://pressgazette.co.uk/most-popular-websites-news-us-monthly/` (accessed Mar. 29, 2022).

[43] M. Mann. *The hockey stick and the climate wars*. Columbia University Press, 2012.

[44] A. V. Mavrodieva, O. K. Rachman, V. B. Harahap, and R. Shaw. Role of social media as a soft power tool in raising public awareness and engagement in addressing climate change. *Climate*, 7(10):122, Oct. 2019. doi: 10.3390/cli7100122

[45] M. McGrath. "Climate change: Five things we have learned from the IPCC report." BBC News at bbc.co.uk/news. `https://www.bbc.com/news/science-environment-58138714` (accessed Mar. 29, 2022).

[46] R. McMahon, M. Stauffacher, and R. Knutti. The unseen uncertainties in climate change: Reviewing comprehension of an IPCC scenario graph. *Climatic Change*, 133(2):141–154, Nov. 2015. doi: 10.1007/s10584-015-1473-4

[47] R. McMahon, M. Stauffacher, and R. Knutti. The scientific veneer of IPCC visuals. *Climatic Change*, 138(3):369–381, Oct. 2016. doi: 10.1007/s10584-016-1758-2

[48] J. Metag, M. S. Schäfer, T. Füchslin, T. Barsuhn, and K. Kleinen-von Königslöw. Perceptions of climate change imagery: Evoked salience and self-efficacy in Germany, Switzerland, and Austria. *Science Communication*, 38(2):197–227, Apr. 2016. doi: 10.1177/1075547016635181

[49] A. Morelli, T. G. Johansen, R. Pidcock, J. Harold, A. Pirani, M. Gomis, I. Lorenzoni, E. Haughey, and K. Coventry. Co-designing engaging and accessible data visualisations: A case study of the IPCC reports. *Climatic Change*, 168(3):26, Oct. 2021. doi: 10.1007/s10584-021-03171-4

[50] R. Newell, A. Dale, and C. Winters. A picture is worth a thousand data points: Exploring visualizations as tools for connecting the public to climate change research. *Cogent Social Sciences*, 2(1):1201885, Dec. 2016. doi: 10.1080/23311886.2016.1201885

[51] T. Nocke, T. Sterzel, M. Böttinger, and M. Wrobel. Visualization of climate and climate change data: An overview. *in Ehlers et al. (Eds.) Digital Earth Summit on Geoinformatics 2008: Tools for Global Change Research (ISDE'08), Wichmann, Heidelberg, pp. 226-232, 2008*, Jan. 2008.

[52] S. O'Neill. More than meets the eye: A longitudinal analysis of climate change imagery in the print media. *Climatic Change*, 163(1):9–26, Nov. 2020. doi: 10.1007/s10584-019-02504-8

[53] S. O'Neill and S. Nicholson-Cole. "Fear won't do it": Promoting positive engagement with climate change through visual and iconic representations. *Science Communication*, 30(3):355–379, Mar. 2009. doi: 10.1177/1075547008329201

[54] S. O'Neill, H. T. P. Williams, T. Kurz, B. Wiersma, and M. Boykoff. Dominant frames in legacy and social media coverage of the IPCC Fifth Assessment Report. *Nature Climate Change*, 5(4):380–385, Apr. 2015. doi: 10.1038/nclimate2535

[55] S. J. O'Neill, M. Boykoff, S. Niemeyer, and S. A. Day. On the use of imagery for climate change engagement. *Global Environmental Change*, 23(2):413–421, Apr. 2013. doi: 10.1016/j.gloenvcha.2012.11.006

[56] S. J. O'Neill and N. Smith. Climate change and visual imagery. *WIREs Climate Change*, 5(1):73–87, Oct. 2014. doi: 10.1002/wcc.249

[57] J. T. Overpeck, G. A. Meehl, S. Bony, and D. R. Easterling. Climate data challenges in the 21st century. *Science*, 331(6018):700–702, Feb. 2011. doi: 10.1126/science.1197869

[58] A. Patt and R. Zeckhauser. Action bias and environmental decisions. *Journal of Risk and Uncertainty*, 21(1):45–72, July 2000. doi: 10.1023/A:1026517309871

[59] W. Pearce, S. Niederer, S. M. Özkula, and N. Sánchez Querubín. The social media life of climate change: Platforms, publics, and future imaginaries. *WIREs Climate Change*, 10(2):e569, 2019. doi: 10.1002/wcc.569

[60] Pew Research Center. In response to climate change, citizens in advanced economies are willing to alter how they live and work. https://www.pewresearch.org/global/2021/09/14/in-response-to-climate-change-citizens-in-advanced-economies-are-willing-to-alter-how-they-live-and-work/, Sept. 2021.

[61] R. Pidcock, K. Heath, L. Messling, S. Wang, A. Pirani, S. Connors, A. Corner, C. Shaw, and M. Gomis. Evaluating effective public engagement: Local stories from a global network of IPCC scientists. *Climatic Change*, 168(3):21, Oct. 2021. doi: 10.1007/s10584-021-03230-w

[62] S. Rebich-Hespanha and R. E. Rice. Dominant visual frames in climate change news stories: Implications for formative evaluation in climate change campaigns. *International Journal of Communication*, 10:4830–4862, 2016.

[63] S. Rebich-Hespanha, R. E. Rice, D. R. Montello, S. Retzloff, S. Tien, and J. P. Hespanha. Image themes and frames in US print news stories about climate change. *Environmental Communication*, 9(4):491–519, Oct. 2015. doi: 10.1080/17524032.2014.983534

[64] D. P. Retchless and C. A. Brewer. Guidance for representing uncertainty on global temperature change maps. *International Journal of Climatology*, 36(3):1143–1159, 2016. doi: 10.1002/joc.4408

[65] W. Samuelson and R. Zeckhauser. Status quo bias in decision making. *Journal of Risk and Uncertainty*, 1(1):7–59, Mar. 1988. doi: 10.1007/BF00055564

[66] B. Schneider. Climate model simulation visualization from a visual studies perspective. *WIREs Climate Change*, 3(2):185–193, Mar. 2012. doi: 10.1002/wcc.162

[67] B. Schneider and T. Nocke. Image politics of climate change: Introduction. In *Image politics of climate change*, pp. 9–25. Transcript-Verlag, Mar. 2014. doi: 10.14361/transcript.9783839426104.intro

[68] S. R. J. Sheppard, A. Shaw, D. Flanders, and S. Burch. Can visualisation save the world? - Lessons for landscape architects from visualizing local climate change. *Digital Design in Landscape Architecture*, Jan. 2008.

[69] C. Tobitt and A. Majid. "National press ABCs: Daily Mail falls below 900k but stays top of pack with Metro". Pressgazette.co.uk. `https://pressgazette.co.uk/most-popular-newspapers-uk-abc-monthly-circulation-figures/` (accessed Mar. 29, 2022).

[70] C. Tominski, J. F. Donges, and T. Nocke. Information visualization in climate research. In *2011 15th International Conference on Information Visualisation*, pp. 298–305. IEEE, 2011. doi: 10.1109/IV.2011.12

[71] W. Turvill. "Top 25 US newspapers by circulation: America's largest titles have lost 20% of print sales since Covid-19 hit". Pressgazette.co.uk. `https://pressgazette.co.uk/biggest-us-newspapers-by-circulation/` (accessed Mar. 29, 2022).

[72] S. L. van der Linden, A. A. Leiserowitz, G. D. Feinberg, and E. W. Maibach. How to communicate the scientific consensus on climate change: Plain facts, pie charts or metaphors? *Climatic Change*, 126(1):255–262, Sept. 2014. doi: 10.1007/s10584-014-1190-4

[73] S. Wang, A. Corner, D. Chapman, and E. Markowitz. Public engagement with climate imagery in a changing digital landscape. *Wiley Interdisciplinary Reviews: Climate Change*, 9(2):e509, Jan. 2018. doi: 10.1002/wcc.509

[74] A. Watson. "Leading cable news networks in the United States in June 2020, by number of primetime viewers". Statista.com. `https://www.statista.com/statistics/373814/cable-news-network-viewership-usa/` (accessed Mar. 29, 2022).

[75] A. Watson. "Leading television channels used for news by consumers in the United Kingdom (UK) from 2013 to 2021". Statista.com. `https://www.statista.com/statistics/266781/leading-tv-news-channels-sources-in-the-united-kingdom-uk/` (accessed Mar. 29, 2022).

[76] H. Wessler, A. Wozniak, L. Hofer, and J. Lück. Global multimodal news frames on climate change: A comparison of five democracies around the world. *The International Journal of Press/Politics*, 21(4):423–445, Oct. 2016. doi: 10.1177/1940161216661848

[77] F. Windhager, G. Schreder, and E. Mayr. On inconvenient images: Exploring the design space of engaging climate change visualizations for public audiences. In R. Bujack, K. Feige, K. Rink, and D. Zeckzer, eds., *7th Workshop on Visualisation in Environmental Sciences, EnvirVis@EuroVis 2019, Porto, Portugal, June 3, 2019*, pp. 1–8. Eurographics Association, 2019. doi: 10.2312/envirvis.20191098

[78] A. Wozniak. Stakeholders' visual representations of climate change. In *Research Handbook on Communicating Climate Change*, Elgar Handbooks in Energy, the Environment and Climate Change, pp. 131–142. Edward Elgar Publishing, Dec. 2020. doi: 10.4337/9781789900408.00023

[79] G. Xexakis and E. Trutnevyte. Empirical testing of the visualizations of climate change mitigation scenarios with citizens: A comparison among Germany, Poland, and France. *Global Environmental Change*, 70:102324, Sept. 2021. doi: 10.1016/j.gloenvcha.2021.102324

A. Appendix

A.1. Selection of Example Visualizations

During the interviews, two pairs of climate change data visualizations were used as a basis for discussion. The example visualizations were selected according to the following logic: the Summary for Policy Makers of the Working Group I contribution to the IPCC's Sixth Assessment Report "Climate Change 2021: The Physical Science Basis" (AR6-WGI-SPM) [32] includes ten central data visualizations explaining the latest science insights behind climate change. We investigated 85 of the most popular online news sources from the UK, the USA, and Germany for articles that were released in response to this publication. The table on the next pages provides an overview of the inspected articles, highlighting if data visualizations were used and if so, if they were copies of the IPCC's visualizations or if they were recreated by the news source. For the sake of completeness, all articles were included in this overview, even if access was denied or if no data visualizations were included.

FIGURES IN AR6-WGI-SPM	Figure name by IPCC	SPM.1	SPM.2	SPM.3	SPM.4	SPM.5	SPM.6	SPM.7	SPM.8	SPM.9	SPM.10	Marked in yellow: No access to the news article (included for reasons of completeness).
	Title abbreviation by authors	GLOBAL-TEMP	WARMING-CONTRIBUTIONS	REGIONAL-CHANGES	FUTURE-EMISSIONS	GLOBAL-CHANGES	EXTREMES	CO2-EMISSIONS	CC-INDICATORS	REGIONS	CO2-AND-WARMING	Marked in grey: Duplicate sources (UK and US) are not counted in the sum.
	Figure discription by IPCC	History of global temperature change and causes of recent warming	Assessed contributions to observed warming in 2010–2019 relative to 1850–1900.	Synthesis of assessed observed and attributable regional changes	Future anthropogenic emissions of key drivers of climate change and warming contributions by groups of drivers for the five illustrative scenarios used in this report.	Changes in annual mean surface temperature, precipitation, and soil moisture.	Projected changes in the intensity and frequency of hot temperature extremes over land, extreme precipitation over land, and agricultural and ecological droughts in drying regions.	Cumulative anthropogenic CO2 emissions taken up by land and ocean sinks by 2100 under the five illustrative scenarios.	Selected indicators of global climate change under the five illustrative scenarios used in this report.	Synthesis of the number of AR6 WGI reference regions where climatic impact-drivers are projected to change.	Near-linear relationship between cumulative CO2 emissions and the increase in global surface temperature.	RECREATION: The source included a data visualization, which was a recreation by the news source. COPY: The source included a data visualization, which was a copy of the original shown in the AR6-WGI-SPM.
UK (28 sources)	Al Jazeera (English version)											https://www.aljazeera.com/news/2021/8/9/climate-report-code-red-for-humanity
												https://www.aljazeera.com/news/2021/8/9/global-warming-quicker-than-feared-un-report
	BBC					RECREATION	RECREATION		RECREATION			https://www.bbc.com/news/science-environment-58138714
		RECREATION				RECREATION			RECREATION			bbc.com/news/science-environment-58130705
												https://www.bbc.com/news/science-environment-58141129
						RECREATION			RECREATION			https://www.bbc.com/news/world-58064485
	Birmingham Mail											no finds
	Channel 4											https://www.channel4.com/news/ipcc-report-is-a-wake-up-call-for-countries-says-alok-sharma
												https://www.channel4.com/news/by/simon-roach/blogs/the-chance-to-meet-climate-targets-almost-gone-warns-un-report
												https://www.channel4.com/news/some-climate-changes-now-irreversible-says-stark-un-report
	Channel 5											no finds
	CNN				RECREATION							https://edition.cnn.com/2021/08/09/world/global-climate-change-report-un-ipcc/index.html
												https://edition.cnn.com/2021/08/09/world/ipcc-climate-key-takeaways/index.html
	Daily Express						RECREATION					https://www.dailyexpress.com.my/news/176068/acceleration-of-global-warming-code-red-for-humanity/
												https://www.dailyexpress.com.my/news/176080/code-red-un-scientists-warn-of-worsening-global-warming/
	Daily Mail	COPY	COPY		COPY	COPY	COPY					https://www.dailymail.co.uk/news/article-9875079/Planet-likely-warm-far-quickly-expected-bombshell-report-warns.html
		RECREATION	COPY		COPY	COPY	COPY					https://www.dailymail.co.uk/news/article-9878309/World-wake-act-curb-climate-change-late-says-Britain.html
	Daily Mirror					COPY						https://www.mirror.co.uk/news/world-news/breaking-doomsday-climate-change-report-24717682
						COPY						https://www.mirror.co.uk/news/uk-news/five-chilling-predictions-doomsday-climate-24719926
												https://www.mirror.co.uk/news/world-news/six-key-lessons-world-must-24723533
	Daily Record											https://www.dailyrecord.co.uk/news/politics/code-red-ipcc-report-climate-24718127
	Daily Star											no finds
	Evening Standard											https://www.standard.co.uk/news/uk/ipcc-climate-change-report-b949752.html
	Financial Times				RECREATION							https://www.ft.com/content/9a11b08c-4fb3-49ec-8939-9d853745bfce
					RECREATION							https://www.ft.com/content/83439010-2fd8-47db-a93d-26f812ae5ee9
	Hello Magazine											no finds
	i											https://inews.co.uk/opinion/ipcc-report-climate-change-disaster-stop-using-fossil-fuels-1142067
												https://inews.co.uk/news/what-intergovernmental-panel-climate-change-ipcc-report-climate-change-global-warming-1141998
	ITV1/ITV Wales/UTV/STV											https://www.itv.com/news/2021-08-08/new-un-report-to-set-out-stark-reality-of-the-climate-crisis
	Liverpool Echo											https://www.liverpoolecho.co.uk/news/uk-world-news/new-un-report-set-out-21260509
	Manchester Evening News											https://www.manchestereveningnews.co.uk/news/uk-news/new-un-report-set-out-21260509
												https://www.manchestereveningnews.co.uk/news/uk-news/widespread-extreme-weather-predicted-code-21262202
	Metro											https://metro.co.uk/2021/08/09/climate-change-report-14-key-findings-from-2021-un-report-15060433/
												https://metro.co.uk/2021/08/09/earth-likely-to-heat-up-by-1-5c-a-decade-earlier-than-expected-15059970/
												https://metro.co.uk/2021/08/09/climate-change-report-heating-from-humans-has-caused-irreparable-damage-to-earth-15060276/
	Sky News											https://news.sky.com/story/climate-change-global-warming-limit-of-1-5c-to-be-hit-in-next-20-years-landmark-un-report-warns-12376737
		RECREATION				COPY			RECREATION			https://news.sky.com/story/climate-change-seven-key-takeaways-from-the-ipcc-climate-change-report-12377264
	Sunday Post	RECREATION										https://www.sundaypost.com/news/uk-news/unequivocal-unprecedented-un-report-sets-out-stark-reality-of-climate-crisis/
	The Guardian	RECREATION										https://www.theguardian.com/science/2021/aug/09/humans-have-caused-unprecedented-and-irreversible-change-to-climate-scientists-warn
		RECREATION			RECREATION				RECREATION			https://www.theguardian.com/business/grogonomics/2021/aug/12/the-ipcc-report-is-a-massive-alert-that-the-time-for-climate-action-is-nearly-gone-but-crucially-not-gone-yet
												https://www.theguardian.com/world/2021/aug/10/ipcc-report-shows-possible-loss-of-entire-countries-within-the-century
		RECREATION										https://www.instagram.com/p/CSXHuKIqCs1/
												https://www.theguardian.com/environment/2021/aug/09/ipcc-reports-verdict-on-climate-crimes-of-humanity-guilty-as-hell
												https://www.theguardian.com/environment/2021/aug/09/climate-crisis-unequivocally-caused-by-human-activities-says-ipcc-report
	The Independent											https://www.independent.co.uk/climate-change/news/ipcc-report-2021-climate-un-b1899193.html
												https://www.independent.co.uk/climate-change/climate-change-ippc-report-johnson-b1899159.html
												https://www.independent.co.uk/climate-change/news/ipcc-report-2021-summary-climate-b1899189.html
												https://www.independent.co.uk/climate-change/news/sea-level-rise-ipcc-report-2021-b1899177.html
	The Observer											no finds (belongs to The Guardian)
	The Sun											https://www.thesun.co.uk/news/15817245/climate-change-un-report-2021-limit/
	The Telegraph											https://www.telegraph.co.uk/environment/2021/08/09/paris-15c-climate-goal-set-breached-within-two-decades/
	The Times											https://www.thetimes.co.uk/article/the-times-view-on-the-ipcc-report-on-climate-change-code-red-sb6qvhj07
												https://www.thetimes.co.uk/article/scientists-unite-to-issue-stark-climate-warning-xxkk7d988
												https://www.thetimes.co.uk/article/ipcc-climate-change-report-a-wake-up-call-for-the-world-l73clz7nf
	Wales Online											https://www.walesonline.co.uk/news/uk-news/new-un-report-set-out-21260509
												https://www.walesonline.co.uk/news/wales-news/devastating-findings-ipcc-warns-climate-21261217

FIGURES IN AR6-WGI-SPM	Figure name by IPCC	SPM.1	SPM.2	SPM.3	SPM.4	SPM.5	SPM.6	SPM.7	SPM.8	SPM.9	SPM.10	Marked in yellow: No access to the news article (included for reasons of completeness).
	Title abbreviation by authors	GLOBAL-TEMP	WARMING-CONTRIBUTIONS	REGIONAL-CHANGES	FUTURE-EMISSIONS	GLOBAL-CHANGES	EXTREMES	CO2-EMISSIONS	CC-INDICATORS	REGIONS	CO2-AND-WARMING	Marked in grey: Duplicate sources (UK and US) are not counted in the sum.
	Figure discription by IPCC	History of global temperature change and causes of recent warming	Assessed contributions to observed warming in 2010–2019 relative to 1850–1900.	Synthesis of assessed observed and attributable regional changes	Future anthropogenic emissions of key drivers of climate change and warming contributions by groups of drivers for the five illustrative scenarios used in this report.	Changes in annual mean surface temperature, precipitation, and soil moisture.	Projected changes in the intensity and frequency of hot temperature extremes over land, extreme precipitation over land, and agricultural and ecological droughts in drying regions.	Cumulative anthropogenic CO2 emissions taken up by land and ocean sinks by 2100 under the five illustrative scenarios.	Selected indicators of global climate change under the five illustrative scenarios used in this report.	Synthesis of the number of AR6 WGI reference regions where climatic impact-drivers are projected to change.	Near-linear relationship between cumulative CO2 emissions and the increase in global surface temperature.	RECREATION: The source included a data visualization, which was a recreation by the news source.
												COPY: The source included a data visualization, which was a copy of the original shown in the AR6-WGI-SPM.
USA (41 sources)	Arizona Republic											https://eu.azcentral.com/story/news/nation/2021/08/09/climate-change-reports-5-most-alarming-findings/5535699001/
	BBC					RECREATION	RECREATION		RECREATION			https://www.bbc.com/news/science-environment-58138714
		RECREATION				RECREATION			RECREATION			bbc.com/news/science-environment-58130705
												https://www.bbc.com/news/science-environment-58141129
						RECREATION			RECREATION			https://www.bbc.com/news/world-58064485
	Boston Globe											https://www.bostonglobe.com/2021/08/09/metro/we-are-fighting-future-humanity-dire-ipcc-report-sparks-calls-urgent-action-climate-change-massachusetts/
												https://www.bostonglobe.com/2021/08/09/science/with-window-act-narrowing-stark-report-worlds-climate-experts/
												https://www.bostonglobe.com/2021/08/09/world/5-things-know-about-new-un-report-climate-change/
												https://www.bostonglobe.com/2021/08/09/science/read-full-climate-change-2021-report-by-uns-ipcc/
	Breitbart											https://www.breitbart.com/news/no-good-news-here-key-ipcc-findings-on-climate-change/
												https://www.breitbart.com/news/landmark-u-n-report-says-some-climate-effects-permanent-still-time-to-avoid-others/
												https://www.breitbart.com/news/world-shudders-at-terrifying-un-climate-report/
	Buffalo News											https://buffalonews.com/news/national/5-key-takeaways-from-the-new-un-report-on-climate-change/collection_64b8ed12-8602-5efa-91c9-b7d89cadfa79.html
	Business Insider											https://www.businessinsider.com/climate-ipcc-report-temperature-rise-20-years-15-degrees-2021-8
												https://www.businessinsider.com/climate-change-impacts-to-last-millennia-ipcc-report-2021-8
												https://www.businessinsider.com/still-time-to-address-climate-change-ipcc-scientists-report-2021-8
	Buzzfeed											no finds
	Chicago Sun Times											https://chicago.suntimes.com/news/2021/8/10/22618670/climate-change-united-nations-report-scientists-warn-global-warming-code-red-extreme-weather
												https://chicago.suntimes.com/2021/8/12/22621508/climate-change-un-report
	Chicago Tribune											https://www.chicagotribune.com/nation-world/ct-aud-nw-warming-climate-united-nations-report-20210809-5exl3r5fmfcd5ohj6lwt2dhbby-story.html
												https://www.chicagotribune.com/nation-world/ct-aud-nw-un-climate-change-report-takeaways-20210809-kclm6clrofbbhpcprjtyb7eltu-story.html
	CNBC											https://www.cnbc.com/2021/08/09/ipcc-report-un-climate-report-delivers-starkest-warning-yet.html
	CNN				RECREATION							https://edition.cnn.com/2021/08/09/world/global-climate-change-report-un-ipcc/index.html
												https://edition.cnn.com/2021/08/09/world/ipcc-climate-key-takeaways/index.html
	Daily Mail	COPY	COPY		COPY	COPY	COPY					https://www.dailymail.co.uk/news/article-9875079/Planet-likely-warm-far-quickly-expected-bombshell-report-warns.html
		RECREATION	COPY		COPY	COPY	COPY					https://www.dailymail.co.uk/news/article-9878309/World-wake-act-curb-climate-change-late-says-Britain.html
	Daily News (New York)											https://www.nydailynews.com/news/national/ny-un-report-global-warming-nears-limits-20210809-z6p75acz3rbgdfrrbng7o3btke-story.html+&cd=1&hl=de&ct=clnk&gl=de
	Dallas Morning News											no finds
	Denver Post											https://www.denverpost.com/2021/08/09/un-climate-report-reaction-colorado-scrambling-to-endure-intensifying-heat-calamities/
	Forbes											https://www.forbes.com/sites/feliciajackson/2021/08/09/its-time-for-a-new-approach-as-ipcc-report-doubles-down-on-need-for-rapid-climate-action/?sh=53cbd0294ce4
		RECREATION			RECREATION							https://www.forbes.com/sites/jamesconca/2021/08/16/latest-ipcc-report-predicts-disasteryet-again-but-not-much-will-happenyet-again/?sh=52fbdc7e37b9
												https://www.forbes.com/sites/frankvangansbeke/2021/08/14/the-ipcc-report--a-bold-and-imaginative-emergency-response-reviewed/?sh=3acbf0ed5f5b
												https://www.forbes.com/sites/brentanalexander/2021/08/15/the-ipcc-climate-report-outlines-an-alarming-future-avoiding-the-worst-means-trying-everything/?sh=201c08c5240b
												https://www.forbes.com/sites/startswithabang/2021/08/10/sorry-skeptics-new-ipcc-report-provides-unprecedented-clarity-about-earths-climate/?sh=1cac44557d85
												https://www.forbes.com/sites/allanmarks/2021/08/09/un-intergovernmental-panel-on-climate-change-issues-a-reality-check-from-scientists/?sh=67ac61a17463
	Fox News											https://www.foxnews.com/us/ipcc-climate-change-reports-claims-challenged-by-skeptics
												https://www.foxnews.com/world/un-report-climate-change-5-things-know
	Honolulu Star Advertiser											https://www.staradvertiser.com/2021/08/09/breaking-news/code-red-u-n-scientists-warn-of-worsening-global-warming/
	Houston Chronicle											https://www.houstonchronicle.com/us-world/article/5-things-to-know-about-the-new-UN-report-on-16375502.php
	HuffPost											https://www.huffpost.com/entry/united-nations-ipcc-climate_n_6110051be4b05f81570b9f50
	Los Angeles Times											https://www.latimes.com/world-nation/story/2021-08-09/5-things-to-know-un-report-climate-change
	Milwaukee Journal Sentinel											https://eu.jsonline.com/story/news/nation/2021/08/09/climate-change-reports-5-most-alarming-findings/5535699001/
												https://eu.jsonline.com/story/news/nation/2021/08/09/ipcc-climate-change-report-released/5535115001/
	MSNBC											https://www.msnbc.com/opinion/new-ipcc-climate-change-report-harrowing-hopeful-n1276389
	NBC News											https://www.nbcnews.com/science/environment/un-releases-blistering-assessment-state-climate-change-rcna1622
	New York Post											https://nypost.com/2021/08/09/un-report-global-warming-is-likely-to-blow-past-paris-limit/
	New York Times											https://www.nytimes.com/2021/08/09/climate/un-climate-report-takeaways.html
												https://www.nytimes.com/2021/08/09/climate/climate-change-report-ipcc-un.html
	Newsday (Long Island)											no finds
	People											https://people.com/human-interest/new-climate-change-report-from-united-nations-warns-humanity-is-at-code/
	Philadelphia Inquirer											https://www.inquirer.com/science/climate/un-climate-report-global-warming-20210809.html
	San Francisco Chronicle											no finds
	Seattle Times											https://www.seattletimes.com/nation-world/a-hotter-future-is-certain-climate-panel-warns-but-how-hot-is-up-to-us/?amp=1
												https://www.seattletimes.com/seattle-news/science/5-things-to-know-about-the-new-un-report-on-climate-change/
	St Louis Post-Dispatch											https://www.stltoday.com/ipcc-assessment-report/pdf_24cdc95c-84e8-520f-856b-d558612f113e.html
												https://www.stltoday.com/weather/5-key-takeaways-from-the-new-un-report-on-climate-change/collection_63bcaa4b-cefa-545d-8cc5-e267ab140c07.html
												https://www.stltoday.com/news/national/leaders-activists-alarmed-not-surprised-by-climate-report/collection_7fc7273c-646e-5aca-9569-c7a3470d9ccd.html
												https://www.stltoday.com/news/national/nowhere-to-run-5-takeaways-from-the-un-report-on-climate-change-plus-global-reaction/article_1353d7e1-363e-5b01-87a7-7e68b251b528.html
												https://www.stltoday.com/news/science/u-n-climate-report-to-save-the-planet-focus-on-cutting-methane/article_c4fc2595-3b5f-5f30-b8b9-8939f35caae1.html
	Star Tribune											https://www.startribune.com/a-code-red-on-climate-change/600086679/
	Star Ledger											https://www.nj.com/news/2021/08/nowhere-to-run-un-report-says-global-warming-nears-limits.html
	Tampa Bay Times											https://www.tampabay.com/news/environment/2021/08/09/earth-warming-likely-to-pass-limit-set-by-leaders-says-latest-un-report/

FIGURES IN AR6-WGI-SPM	Figure name by IPCC	SPM.1	SPM.2	SPM.3	SPM.4	SPM.5	SPM.6	SPM.7	SPM.8	SPM.9	SPM.10	Marked in yellow: No access to the news article (included for reasons of completeness).
	Title abbreviation by authors	GLOBAL-TEMP	WARMING-CONTRIBUTIONS	REGIONAL-CHANGES	FUTURE-EMISSIONS	GLOBAL-CHANGES	EXTREMES	CO2-EMISSIONS	CC-INDICATORS	REGIONS	CO2-AND-WARMING	Marked in grey: Duplicate sources (UK and US) are not counted in the sum.
	Figure discription by IPCC	History of global temperature change and causes of recent warming	Assessed contributions to observed warming in 2010–2019 relative to 1850–1900.	Synthesis of assessed observed and attributable regional changes	Future anthropogenic emissions of key drivers of climate change and warming contributions by groups of drivers for the five illustrative scenarios used in this report.	Changes in annual mean surface temperature, precipitation, and soil moisture.	Projected changes in the intensity and frequency of hot temperature extremes over land, extreme precipitation over land, and agricultural and ecological droughts in drying regions.	Cumulative anthropogenic CO2 emissions taken up by land and ocean sinks by 2100 under the five illustrative scenarios.	Selected indicators of global climate change under the five illustrative scenarios used in this report.	Synthesis of the number of AR6 WGI reference regions where climatic impact-drivers are projected to change.	Near-linear relationship between cumulative CO2 emissions and the increase in global surface temperature.	RECREATION: The source included a data visualization, which was a recreation by the news source. COPY: The source included a data visualization, which was a copy of the original shown in the AR6-WGI-SPM.
USA (41 sources, continuation)	The Guardian	RECREATION										https://www.theguardian.com/science/2021/aug/09/humans-have-caused-unprecedented-and-irreversible-change-to-climate-scientists-warn
		RECREATION			RECREATION				RECREATION			https://www.theguardian.com/business/grogonomics/2021/aug/12/the-ipcc-report-is-a-massive-alert-that-the-time-for-climate-action-is-nearly-gone-but-crucially-not-gone-yet
												https://www.theguardian.com/world/2021/aug/10/ipcc-report-shows-possible-loss-of-entire-countries-within-the-century
		RECREATION										https://www.instagram.com/p/CSXHuKIqCs1/
												https://www.theguardian.com/environment/2021/aug/09/ipcc-reports-verdict-on-climate-crimes-of-humanity-guilty-as-hell
												https://www.theguardian.com/environment/2021/aug/09/climate-crisis-unequivocally-caused-by-human-activities-says-ipcc-report
	The Wall Street Journal											https://www.wsj.com/articles/ipcc-climate-change-report-gives-a-less-extreme-but-more-sobering-outlook-11628697997
												https://www.wsj.com/articles/some-climate-change-effects-may-be-irreversible-u-n-panel-report-says-11628496000
	US News											https://www.usnews.com/news/world/articles/2021-08-09/un-sounds-clarion-call-over-irreversible-climate-impacts-by-humans
												https://www.usnews.com/news/world/articles/2021-08-09/5-things-to-know-about-the-new-un-report-on-climate-change
												https://www.usnews.com/news/world/articles/2021-08-09/explainer-the-un-climate-reports-five-futures-decoded
	USA Today											https://eu.usatoday.com/story/news/nation/2021/08/09/ipcc-climate-change-report-released/5535115001/
												https://eu.usatoday.com/story/news/nation/2021/08/09/climate-change-reports-5-most-alarming-findings/5535699001/
	Washington Post											https://www.washingtonpost.com/climate-environment/2021/08/10/ipcc-report-un-takeaways/
												https://www.washingtonpost.com/climate-environment/2021/08/09/ipcc-climate-report-global-warming-greenhouse-gas-effect/
												https://www.washingtonpost.com/weather/2021/08/09/ipcc-2021-extreme-weather-climate/
	Yahoo Finance											no finds
GERMAN WEBSITES (16 sources)	Bild.de											https://www.bild.de/ratgeber/wissenschaft/ratgeber/bericht-des-weltklimarates-es-wird-sehr-dramatisch-fuer-uns-werden-77328716.bild.html
	T-Online											https://www.t-online.de/nachhaltigkeit/id_90599288/weltklimarat-ipcc-bericht-viele-klimaschaeden-in-europa-nicht-verhinderbar.html
												https://www.t-online.de/nachrichten/panorama/id_90593476/weltklimarat-klimabericht-sagt-drastische-klimawandel-folgen-voraus.html
	n-tv.de											https://www.n-tv.de/wissen/Weltklimarat-Erde-erwaermt-sich-bis-2030-um-1-5-Grad-article22731557.html
												https://www.n-tv.de/wissen/Vor-diesen-Folgen-warnen-die-Klima-Experten-article22731957.html
	Der Spiegel	COPY					RECREATION					https://www.spiegel.de/wissenschaft/natur/ipcc-was-der-neue-bericht-des-weltklimarats-fuer-uns-bedeutet-a-8fec8732-2a82-465a-9ac3-c3467cf17672
							RECREATION					https://www.spiegel.de/wissenschaft/mensch/ipcc-weltklimabericht-1-5-grad-koennte-schneller-eintreten-als-angenommen-a-444d2136-92e4-4feb-bf52-982e2b6c9025
												https://www.spiegel.de/wissenschaft/mensch/klimabericht-des-ipcc-der-planet-schwebt-in-lebensgefahr-und-mit-ihm-seine-bewohner-a-9971f00b-6ce1-4920-a075-d6385483a9a9
												https://www.spiegel.de/wissenschaft/so-werden-die-werte-aus-dem-klimabericht-berechnet-a-5dcc3a12-9149-436e-9a73-40d41dfff113
	Ippen.Media											no finds
	Focus Online											https://www.focus.de/perspektiven/entwicklung-foerdern-klima-schuetzen/bericht-von-234-experten-aus-66-laendern-klimawandel-bereits-unumkehrbar_id_13570281.html
									RECREATION			https://www.focus.de/wissen/klima/klimaschutz/braende-und-flut-katastrophe-erst-der-anfang-waldbraende-und-hochwasser-erst-der-anfang-5-klimameldungen-die-uns-wachruetteln-sollten_id_13576000.html
	Welt				RECREATION				RECREATION			https://www.welt.de/wissenschaft/article233011855/IPCC-und-Klimawandel-Globale-Erwaermung-und-die-Folgen-das-steht-im-neuen-UN-Klimabericht.html
												https://www.welt.de/wissenschaft/article232028539/IPCC-Weltklimarat-warnt-eindringlich-vor-Verfehlen-des-1-5-Grad-Ziels.html
												https://www.welt.de/wissenschaft/plus233018113/UN-Klimabericht-Eine-Prognose-muss-Sorge-machen-eine-wurde-uebertrieben.html
	upday											no finds
	RTL.de											https://www.rtl.de/cms/ipcc-bericht-weltklimarat-veroeffentlicht-neuen-bericht-zum-klimawandel-4810545.html
												https://www.rtl.de/cms/ipcc-bericht-wissenschaftler-sind-besorgt-wir-haben-ein-sehr-ernstes-problem-4810282.html
												https://www.rtl.de/cms/klimarat-warnt-vor-dramatischen-folgen-des-klimawandels-aktueller-klimaschutz-reicht-nicht-aus-4810634.html
	Funke Medien NRW											https://www.waz.de/politik/klimakrise-waldbraende-flut-bericht-weltklimarat-id232989897.html
												https://www.waz.de/politik/ipcc-weltklimarat-klimawandel-erderwaermung-meeresspiegel-id233000809.html
	Zeit Online											https://www.zeit.de/wissen/umwelt/2021-08/klimawandel-ipcc-bericht-weltklimarat-erderwaermung-extremwetter/seite-2
												https://www.zeit.de/wissen/2021-08/weltklimarat-ipcc-bericht-klimapolitik-klimawandel-prognose?utm_referrer=https%3A%2F%2Fwww.google.com%2F
		RECREATION							RECREATION			https://www.zeit.de/wissen/umwelt/2021-08/ipcc-weltklimabericht-klimawandel-grafik-temperaturanstieg-uebersicht?utm_referrer=https%3A%2F%2Fwww.google.com%2F
	RND											https://www.rnd.de/wissen/klimawandel-weltklimarat-ipcc-legt-bericht-vor-klimaerwaermung-ist-weit-verbreitet-schnell-und-H4M4RBAYXVDPXBJFM5BQAAJ7WA.html
												https://www.rnd.de/wissen/klimabericht-des-ipcc-weltklimarats-die-allerletzte-warnung-zum-klimawandel-CUHVSCVHTFGJHMJWT63RDQK5FI.html
												https://www.rnd.de/politik/weltklimarat-bericht-klimawandel-noch-schlimmer-als-befuerchtet-7F4VWHBERPMUNUYHNZJPYQ4U2I.html
	Süddeutsche.de	RECREATION					RECREATION		RECREATION			https://www.sueddeutsche.de/wissen/klimawandel-ipcc-weltklimarat-erderwaermung-co2-duerre-starkregen-meeresspiegel-1.5377150
												https://www.sueddeutsche.de/wissen/ipcc-weltklimarat-bericht-1.5377741
												https://www.sueddeutsche.de/politik/klimawandel-ipcc-weltklimarat-erderwaermung-1.5377816
												https://www.sueddeutsche.de/kolumne/klimawandel-ist-die-katastrophe-noch-abzuwenden-1.5386253
												https://www.sueddeutsche.de/wissen/klima-klimabericht-sagt-drastische-klimawandel-folgen-voraus-dpa.urn-newsml-dpa-com-20090101-210809-99-773213
	FAZ.net					RECREATION						https://www.faz.net/aktuell/wissen/bericht-des-weltklimarats-ipcc-klimakrise-weltweit-spuerbar-17476855.html
												https://www.faz.net/aktuell/politik/weltklimabericht-zum-klimawandel-fakten-fuer-die-politik-17477922.html
												https://www.faz.net/aktuell/wissen/so-steht-die-sache-um-den-klimawandel-17483563.html
												https://www.faz.net/aktuell/gesellschaft/hitze-und-andere-wetterextreme-weltklimarat-stellt-neuen-bericht-zur-erderwaermung-vor-17477124.html
												https://www.faz.net/aktuell/gesellschaft/laut-weltklimarat-erderwaermung-eindeutig-menschengemacht-17477334.html
	Stern											https://www.stern.de/panorama/wissen/weltklimabericht--das-sind-die-wichtigsten-aussagen-30650892.html
												https://www.stern.de/panorama/wissen/weltklimabericht--erde-heizt-sich-schneller-auf-als-befuerchtet---klimawandel-zweifelsfrei-menschengemacht-30650682.html
												https://www.stern.de/news/ipcc-bericht--erderwaermung-um-1-5-grad-wird-bereits-2030-erreicht-30650806.html
	Tagesspiegel											https://www.tagesspiegel.de/politik/bericht-des-weltklimarats-ipcc-wo-sich-die-klimakrise-am-deutlichsten-zeigt/27496128.html
												https://www.tagesspiegel.de/wissen/weltklimarat-zur-klimakrise-die-1-5-grad-grenze-koennte-schon-2030-ueberschritten-werden/27496374.html
												https://www.tagesspiegel.de/politik/bericht-des-weltklimarats-es-ist-noch-nicht-zu-spaet/27497566.html
Total: 85 sources	SUM (ALL)	12	2	0	8	9	7	0	9	0	0	
	SUM (RECREATIONS)	10	0	0	6	4	5	0	9	0	0	

A.2. Participant Information and Declaration of Consent

Participants were contacted via an e-mail inquiry and were provided with a detailed participant information sheet, which can be found on the following pages. The participant information sheet contains information about the purpose and the procedure of the study, benefits, risks and costs of taking part, as well as rights of the participants and the data collection policy. Further questions from the participants were discussed upfront via e-mail or before the start of the interview. Finally, participants were asked to sign a declaration of consent form stating that they read and understood the information before the recorded interviews took place.

Information for participants and declaration of consent to participate in the study:

Understanding Climate Change Data

Dear participant,

We would like to invite you to participate in the study mentioned above. Your participation in this study is voluntary. You can refuse to participate at any time without having to give a reason, or also withdraw your agreement to participate once the study has already started. There will be no negative consequences for you if you refuse to participate or if you withdraw from this study early.

This kind of study is necessary to gain new, reliable academic research results. However, your written consent to participate in the study is an indispensable prerequisite for us to conduct this study. Please take time to read the following information carefully, and do not hesitate to ask questions.

Please only sign the declaration of consent

- if you have fully understood the type and procedure of the study,
- if you are willing to give your consent to participate, and
- if you are aware of your rights as a participant in this study.

1. What is the purpose of this study?

This study is concerned with how people make sense of common data visualizations about climate change.

2. What is the procedure of the study?

In the course of the study, we conduct one-time interviews with each of the participants, which can be held either remote or in-person according to participants preferences as well as COVID-19 regulations. The participant should have knowledge of aspects of climate change and be fluent in the English language. No additional qualifications are required.

During the interview, you will briefly be asked about your background related to climate change / data visualization / communication science. We will then ask you questions about climate change data visualizations and how people make sense of them. There is no right or wrong answer, we are solely interested in your professional opinion on these topics and on the visualizations. Our conversation will be audio-recorded. In total, this will take approximately 40 - 60 minutes.

3. What are the benefits of participating in the study?

It is hoped that this research will add to the currently existing knowledge of how climate change data visualizations are understood by people and can aid in developing useful tools that help to work with and interpret data visualizations.

4. What are the possible risks of taking part in this study? Could participants experience any discomfort or other side effects?

No risks are known for participants in this study.

5. Does participating in the study have any other effects on participants' lifestyles? What are the obligations resulting from participating?

No other effects or obligations result from participating in this study.

6. What should participants do if they experience symptoms of complaints, unwanted side effects and/or injuries?

Participants can stop participation at any time without giving a reason.

7. In what cases is it necessary that participants withdraw from the study early?

Participants can stop participation at any time without giving a reason.

8. How will the data collected in this study be used?

The recordings will be treated with the strictest confidentiality and will eventually be destroyed after they have been transcribed. The data will be password protected and stored on university servers. Only members of the research team, who are obliged to maintain secrecy, can access the data. Your data will be pseudonymised (through the allocation of an ID number, under which the data will be saved). This way, those who do not have the "key" will not be able to deduce any information about your person. Your contact information will not be shared with anyone else without your permission.

We discourage you from disclosing personal or sensitive information. You will never be mentioned by name, without exception. Information or statements that might reveal your identity (e.g. name, institution/place of employment, etc.) are not transcribed. There will be an overview of how many and what type of experts took part in the study, however, this does not contain any information that could be indicative of your identity. Collected personal data are presented separately from the participant`s statements so that no conclusion can be drawn as to which statements can be attributed to which participant. In cases where this is not possible for any reason, you will be contacted whether you agree to the publication of the quotation or not. This quote will only be included in the master's thesis or a publication with written consent.

The following types of personal data are gathered in the context of the interviews: job role, associated discipline/research area, age, professional/personal experience in relevant areas (e.g. number of years of experience, different areas). This data is only transcribed and used if it does not reveal your identity. Answering any question is voluntary.

You can withdraw your interview data for up to two weeks after the interview took place with an informal request, e.g. via email to Regina Schuster (a11830174@unet.univie.ac.at), without giving a reason. You can request both a transcript of the recorded interview as well as information about the results. The results of the data gathered will be analysed and can be presented at scientific conferences, and/or published in conference proceedings or journals.

9. Will there be any costs for the participants? Will they receive reimbursement or remuneration?

You will not receive reimbursement for incurred costs, nor will you receive remuneration. You will not incur any costs from participating in this study.

10. Possibility to discuss further questions

If a question appears unclear, far-fetched or difficult, you are welcome to interrupt and ask for clarification, but also to omit or refuse to answer without giving a reason. Moreover, you have the right to have questions about the procedure answered (unless answering these questions would interfere with the study's outcome).

If you have any questions regarding this information sheet, please ask the researcher before the beginning of the study.

If you have any further questions about the study in general or the rights of the participants, you are welcome to contact us: a11830174@unet.univie.ac.at

Trial leader	Name: Regina Maria Veronika Schuster E-mail: a11830174@unet.univie.ac.at Phone: +49-1573-9017207
Project leader	Name: Laura Koesten E-mail: laura.koesten@univie.ac.at Phone: +43-1-4277-79020

11. Declaration of consent

Name of the participant: .....

Date of birth: .....

I agree to participate in the study Understanding Climate Change Data.

Regina Schuster provided me with clear and detailed information about the objectives, significance and scope of the study, as well as about the requirements resulting from my participation in the study. In addition, I have read this information text for participants and the declaration of consent. The study coordinator answered all my questions sufficiently and in a comprehensible manner. I had enough time to decide whether I would like to participate in this study. At the moment, I have no further questions.

I will follow the instructions that are necessary for conducting this study. However, I reserve the right to end my voluntary participation at any time, without this being to my disadvantage. If I want to withdraw from the study, I can do so at any time by contacting Regina Schuster, either in writing or verbally.

At the same time, I agree that the data collected in this study are recorded and analysed. I agree that my data is permanently saved electronically in pseudonymised form. The data are saved in a form that is only accessible to the project management and are secured according to current standards. If I want my data to be deleted at a later time, I can arrange for it by contacting Regina Schuster (a11830174@unet.univie.ac.at) either in writing or via telephone, and without having to give a reason.

I have read and understood the information for participants. I had the opportunity to ask all the questions I was interested in. My questions were answered fully and in a comprehensible manner.

I have received a copy of this information for participants and a declaration of consent.

.....
(Date and signature of the participant)

.....
(Date, name and signature of the study coordinator)

A.3. Overview of the Results

The interviews were transcribed and analyzed using the qualitative data analysis software Atlas.ti. Codes were created by systematically going through the interview transcriptions and identifying themes. With a total of 260 resulting codes, the interviews were analyzed a second time to ensure correct assignment. The codes were structured according to the following groups: demographics, climate change, climate change communication, data visualization, example visualization pair 1, and example visualization pair 2. The tables on the following pages show an overview of the results according to those groups. Note, that we excluded demographics and ratings in this overview. The columns on the right indicate participants' expertise (CC for climate change, SC for science communication, VIS for data visualization, sum of all groups) and the numbers show how many participants mentioned the specific aspect.

CLIMATE CHANGE					
TOPIC	STATEMENT	CC	SC	VIS	SUM
Main climate change topics currently (relevant aspects).	Responsibility	4	-	1	5
The role of companies and governments in fighting climate change.	Companies and governments play essential roles	5	-	-	5
The role of companies and governments in fighting climate change.	Regulations are neccessary	5	-	-	5
Main consequences of climate change on society.	Extreme weather events	4	-	-	4
Main consequences of climate change on society.	Consequences depend on the region	4	-	-	4
Main consequences of climate change on society.	Consequences depend on social status	4	-	-	4
Main climate change topics currently (relevant aspects).	Mitigation policies	3	-	-	3
Most important messages in terms of research results that people need to understand in order to improve the public discourse on the topic of CC.	Substantial changes are neccessary	2	-	1	3
Reasons for the low efforts from companies and governments to fight climate change.	Political reasons	3	-	-	3
Reasons for the low efforts from companies and governments to fight climate change.	Profits / costs	3	-	-	3
Actions indivuduals can take in fighting climate change.	Change of consumption	2	-	-	2
Actions indivuduals can take in fighting climate change.	Lack of action	2	-	-	2
Actions indivuduals can take in fighting climate change.	Reduce meat consumption	2	-	-	2
Actions indivuduals can take in fighting climate change.	Change means of transportation	2	-	-	2
Main consequences of climate change on society.	There will be beneficial consequences in some regions	2	-	-	2
Main consequences of climate change on society.	Economic consequences	2	-	-	2
Main consequences of climate change on society.	Migration	2	-	-	2
Main climate change topics currently (relevant aspects).	Communication	2	-	-	2
Main climate change topics currently (relevant aspects).	Emotions	2	-	-	2
Main climate change topics currently (relevant aspects).	Existence and causes of climate change	1	-	1	2
Main climate change topics currently (relevant aspects).	Ignorance	1	-	1	2
Most important messages in terms of research results that people need to understand in order to improve the public discourse on the topic of CC.	Everybody can do something	2	-	-	2
Most important messages in terms of research results that people need to understand in order to improve the public discourse on the topic of CC.	We need to act now	1	-	1	2
Reasons for the low efforts from companies and governments to fight climate change.	Resistance to change	2	-	-	2
The role of companies and governments in fighting climate change.	It is important that companies and governments interact	2	-	-	2
Actions indivuduals can take in fighting climate change.	Reduce flights	1	-	-	1
Main consequences of climate change on society.	Consequences concerning the health situation	1	-	-	1
Main climate change topics currently (research areas).	Carbon cycle	1	-	-	1
Main climate change topics currently (research areas).	Circulation changes	1	-	-	1
Main climate change topics currently (research areas).	Climate sensitivity	1	-	-	1
Main climate change topics currently (research areas).	Digital twin modelling	1	-	-	1
Main climate change topics currently (research areas).	Warming seas	1	-	-	1
Main climate change topics currently (relevant aspects).	Complexity	1	-	-	1
Main climate change topics currently (relevant aspects).	Education	1	-	-	1
Main climate change topics currently (relevant aspects).	Manipulation	1	-	-	1
Main climate change topics currently (relevant aspects).	Political issues	1	-	-	1
Most important messages in terms of research results that people need to understand in order to improve the public discourse on the topic of CC.	Climate change affects everybody	1	-	-	1
Most important messages in terms of research results that people need to understand in order to improve the public discourse on the topic of CC.	Climate change is human-driven	1	-	-	1
Most important messages in terms of research results that people need to understand in order to improve the public discourse on the topic of CC.	Extreme events are unpredictable	1	-	-	1
Most important messages in terms of research results that people need to understand in order to improve the public discourse on the topic of CC.	Need for mitigation policies beyond 1.5 / 2 degrees warming	1	-	-	1
Most important messages in terms of research results that people need to understand in order to improve the public discourse on the topic of CC.	Uncertainty does not mean we know nothing	1	-	-	1
Most important messages in terms of research results that people need to understand in order to improve the public discourse on the topic of CC.	We already are in a catastrophic situation	1	-	-	1
Reasons for the low efforts from companies and governments to fight climate change.	Insufficient understanding	1	-	-	1
Reasons for the low efforts from companies and governments to fight climate change.	Complexity of the topic	1	-	-	1
Reasons for the low efforts from companies and governments to fight climate change.	Resources / focus in developing countries	1	-	-	1
Reasons for the low efforts from companies and governments to fight climate change.	Lack of willingness	1	-	-	1
Reasons for the low efforts from companies and governments to fight climate change.	Social justice	1	-	-	1
The role of companies and governments in fighting climate change.	Climate change will become an economic problem	1	-	-	1

A. Appendix

CLIMATE CHANGE COMUNICATION					
TOPIC	**STATEMENT**	**CC**	**SC**	**VIS**	**SUM**
Aspects of public climate change communication.	Challenge of communicating / understanding uncertainty	4	2	2	8
Reasons for lacking awareness or understanding among the public concerning climate change and its consequences.	Differentiation between awareness and understanding	5	-	-	5
Aspects of public climate change communication.	Importance of training journalists	3	1	-	4
Aspects of scientific climate change communication.	Irrelevance of academic journals for communication to the public	4	-	-	4
Aspects of public climate change communication.	Importance of news media	3	-	-	3
Reasons for lacking awareness or understanding among the public concerning climate change and its consequences.	Complexity of the topic	2	-	1	3
Aspects of public climate change communication.	Different roles of journalism	1	1	-	2
Aspects of public climate change communication.	Importance of social media	2	-	-	2
Aspects of public climate change communication.	Importance of special issues	2	-	-	2
Reasons for lacking awareness or understanding among the public concerning climate change and its consequences.	Limited attention	2	-	-	2
Reasons for lacking awareness or understanding among the public concerning climate change and its consequences.	Lack of socialization / eductaion	1	-	1	2
Aspects of scientific climate change communication.	Language barriers	2	-	-	2
Aspects of public climate change communication.	Decreasing quality of journalism	1	-	-	1
Aspects of public climate change communication.	Challenge of filtering information	1	-	-	1
Aspects of public climate change communication.	Importance of funding	1	-	-	1
Reasons for lacking awareness or understanding among the public concerning climate change and its consequences.	Lack of personal impact	1	-	-	1
Aspects of scientific climate change communication.	Role of science in a country	1	-	-	1

CLIMATE CHANGE DATA VISUALIZATIONS					
TOPIC	STATEMENT	CC	SC	VIS	SUM
Background knowledge needed to interpret data visualizations correctly.	Need	4	5	5	14
Assessment of the participant concerning the accessibility of climate change data visualizations.	Difficult	4	6	3	13
Background knowledge needed to interpret data visualizations correctly.	Insufficient teaching	4	4	4	12
Assessment whether the participant would first look at the data visualization or read the text when presented with an article about climate change.	First attention: visualization	5	3	3	11
Aspects that influence the quality of data visualizations.	Importance of quality	4	4	2	10
The benefits of using data visualizations, for example when communicating climate change topics.	Attention, engagement	3	3	3	9
The drawbacks of using data visualizations, for example when communicating climate change topics.	Manipulation (intentional)	2	3	4	9
Judgement whether common news sources like newspapers should make more or less use of data visualizations.	Common news sources should make greater use of data visualizations	3	2	3	8
The participants opinion about interactive data visualizations.	Increased engagement	2	4	2	8
Aspects that influence the quality of data visualizations.	Combination of text and visualization	3	2	2	7
Aspects that influence the quality of data visualizations.	Simplicity / complexity reduction	3	3	1	7
The participants opinion about interactive data visualizations.	Limited accessibility / increased complexity	1	2	4	7
The participants opinion about interactive data visualizations.	Limited engagement	-	4	3	7
The benefits of using data visualizations, for example when communicating climate change topics.	Possibilities to show data	-	3	3	6
The benefits of using data visualizations, for example when communicating climate change topics.	Visual preference	3	2	1	6
The benefits of using data visualizations, for example when communicating climate change topics.	Approachability, accessibility	2	3	-	5
The benefits of using data visualizations, for example when communicating climate change topics.	Complexity reduction	4	1	-	5
The drawbacks of using data visualizations, for example when communicating climate change topics.	Lack of visual literacy	1	1	3	5
The drawbacks of using data visualizations, for example when communicating climate change topics.	Misinterpretation	2	2	1	5
The drawbacks of using data visualizations, for example when communicating climate change topics.	Visualizing uncertainty	2	-	3	5
Aspects that influence the quality of data visualizations.	Adaption to the target audience	-	2	3	5
Aspects that influence the quality of data visualizations.	Optimization for different channels	-	3	2	5
Aspects that influence the quality of data visualizations.	Purpose / intent / main message	1	2	2	5
Aspects that influence the quality of data visualizations.	Show uncertainty (trust)	3	2	-	5
Assessment of the participant concerning the accessibility of climate change data visualizations.	Depends on design	1	2	2	5
Assessment of the participant concerning the accessibility of climate change data visualizations.	Uncertainty	1	2	2	5
Assessment whether the participant would first look at the data visualization or read the text when presented with an article about climate change.	First attention depends on quality of the visual	-	4	-	4
The drawbacks of using data visualizations, for example when communicating climate change topics.	(Over-)Simplification	1	3	-	4
The drawbacks of using data visualizations, for example when communicating climate change topics.	Ambiguity / misleading (unintentional)	1	2	1	4
The drawbacks of using data visualizations, for example when communicating climate change topics.	Missing involvement / time	2	2	-	4
Aspects that influence the quality of data visualizations.	Infographics	-	2	2	4
Aspects that influence the quality of data visualizations.	Story telling	-	1	3	4
Aspects that influence the quality of data visualizations.	Visualization design	1	3	-	4
The participants opinion about interactive data visualizations.	Increased relatedness	1	-	3	4
Assessment of the participant concerning the accessibility of climate change data visualizations.	Complexity of the topic	2	2	-	4
Background knowledge needed to interpret data visualizations correctly.	Improvements in teaching	-	1	3	4
The drawbacks of using data visualizations, for example when communicating climate change topics.	Accessibility for visually impaired persons	1	1	1	3
Aspects that influence the quality of data visualizations.	Co-design process	1	2	-	3
Aspects that influence the quality of data visualizations.	Data quality / data choice	-	1	2	3
Aspects that influence the quality of data visualizations.	Guidance of user perception	1	-	2	3
Aspects that influence the quality of data visualizations.	Relatability	-	1	2	3
Aspects that influence the quality of data visualizations.	Scales / axes	-	1	2	3
Aspects that influence the quality of data visualizations.	Visualization type	-	2	1	3

A. Appendix

CLIMATE CHANGE DATA VISUALIZATIONS					
TOPIC	STATEMENT	CC	SC	VIS	SUM
The participants opinion about interactive data visualizations.	Allows for high amounts of data	-	1	2	3
The participants opinion about interactive data visualizations.	Hard / expensive to realize	1	2	-	3
The participants opinion about interactive data visualizations.	Suitable for some purposes	1	1	1	3
Assessment of the participant concerning the accessibility of climate change data visualizations.	Colors	-	1	2	3
Assessment of the participant concerning the accessibility of climate change data visualizations.	Scales / axes	1	-	2	3
Assessment whether the participant would first look at the data visualization or read the text when presented with an article about climate change.	First attention depends on placement of the visual	-	-	2	2
Judgement whether common news sources like newspapers should make more or less use of data visualizations.	Usage depends on purpose	-	1	1	2
Judgement whether common news sources like newspapers should make more or less use of data visualizations.	Usage depends on quality	-	2	-	2
Judgement whether common news sources like newspapers should make more or less use of data visualizations.	No opinion	2	-	-	2
The drawbacks of using data visualizations, for example when communicating climate change topics.	Emphasize / focus	-	1	1	2
The drawbacks of using data visualizations, for example when communicating climate change topics.	Wronful reuse	-	1	1	2
Aspects that influence the quality of data visualizations.	Amount of information	-	2	-	2
Aspects that influence the quality of data visualizations.	Clarity	1	1	-	2
Aspects that influence the quality of data visualizations.	Expertise	1	1	-	2
Aspects that influence the quality of data visualizations.	Iterative design process	1	1	-	2
Aspects that influence the quality of data visualizations.	Thought / time / funding	1	-	1	2
The participants opinion about interactive data visualizations.	High potential / powerful	1	1	-	2
Assessment of the participant concerning the accessibility of climate change data visualizations.	Easy	1	-	1	2
Assessment of the participant concerning the accessibility of climate change data visualizations.	Problems with basic literacy	1	1	-	2
Assessment of the participant concerning the accessibility of climate change data visualizations.	Uncommon visualization types	-	1	1	2
Background knowledge needed to interpret data visualizations correctly.	No specific need	1	1	-	2
Assessment whether the participant would first look at the data visualization or read the text when presented with an article about climate change.	First attention: both	-	1	-	1
Assessment whether the participant would first look at the data visualization or read the text when presented with an article about climate change.	First attention: text	1	-	-	1
Judgement whether common news sources like newspapers should make more or less use of data visualizations.	Good balance	-	-	1	1
The benefits of using data visualizations, for example when communicating climate change topics.	Basis for discussion	1	-	-	1
The drawbacks of using data visualizations, for example when communicating climate change topics.	Accessibility	-	1	-	1
The drawbacks of using data visualizations, for example when communicating climate change topics.	Approximation	1	-	-	1
The drawbacks of using data visualizations, for example when communicating climate change topics.	Good design is a challenge	-	1	-	1
The drawbacks of using data visualizations, for example when communicating climate change topics.	Overestimation own experience	1	-	-	1
The drawbacks of using data visualizations, for example when communicating climate change topics.	Refusal	-	1	-	1
Aspects that influence the quality of data visualizations.	Include a headline	-	-	1	1
Aspects that influence the quality of data visualizations.	Size / position	1	-	-	1
Aspects that influence the quality of data visualizations.	Smooth lines	-	1	-	1
The participants opinion about interactive data visualizations.	Good for historical data	1	-	-	1
The participants opinion about interactive data visualizations.	Standardization of usage	-	-	1	1
The participants opinion about interactive data visualizations.	Only if needed	-	1	-	1
Assessment of the participant concerning the accessibility of climate change data visualizations.	Predictions / simulations	-	-	1	1
Assessment of the participant concerning the accessibility of climate change data visualizations.	Scatter plots	-	-	1	1

EXAMPLE VISUALIZATION PAIR 1 (Figure 3.3 and Figure 3.4)					
TOPIC	STATEMENT	CC	SC	VIS	SUM
The participant's opinion whether Figure 3.3 (BBC) is easy or difficult for lay people to interpret.	Easy	4	3	2	9
The participant's assessment of the quality of Figure 3.3 (BBC).	Medium	4	3	1	8
Positive criticism in regard to Figure 3.3 (BBC).	No uncertainty	1	2	5	8
The participant's preference concerning the two presented visualizations Figure 3.3 (BBC) and Figure 3.4 (IPCC).	Preference depens on purpose	1	3	4	8
The participant's assessment of the quality of Figure 3.3 (BBC).	Good	2	2	3	7
Negative criticism in regard to Figure 3.3 (BBC).	Colors	2	3	2	7
Negative criticism in regard to Figure 3.3 (BBC).	Too much text	2	3	2	7
Negative criticism in regard to Figure 3.3 (BBC).	Unclear wording / explanations	2	3	2	7
The participant's opinion whether Figure 3.3 (BBC) is easy or difficult for lay people to interpret.	Difficult	2	3	1	6
Negative criticism in regard to Figure 3.3 (BBC).	Missing Annotations	2	1	3	6
The participant's opinion whether Figure 3.3 (BBC) is easy or difficult for lay people to interpret.	Depends on reader	-	3	2	5
Negative criticism in regard to Figure 3.3 (BBC).	Missing relatability / consequences	-	1	4	5
Negative criticism in regard to Figure 3.3 (BBC).	Visualization type	1	2	2	5
Positive criticism in regard to Figure 3.3 (BBC).	Annotations	1	-	3	4
Negative criticism in regard to Figure 3.3 (BBC).	Complexity	2	1	1	4
Negative criticism in regard to Figure 3.3 (BBC).	Unclear main message	1	2	1	4
Positive criticism in regard to Figure 3.4 (IPCC).	Colors	1	1	2	4
Positive criticism in regard to Figure 3.4 (IPCC).	Uncertainty	2	1	1	4
Negative criticism in regard to Figure 3.4 (IPCC).	Annotations	2	1	1	4
Positive criticism in regard to Figure 3.3 (BBC).	Colors	-	-	3	3
Positive criticism in regard to Figure 3.3 (BBC).	Simplification	1	1	1	3
Positive criticism in regard to Figure 3.3 (BBC).	Title	-	1	2	3
Negative criticism in regard to Figure 3.3 (BBC).	Degrees Celcius	-	2	1	3
Negative criticism in regard to Figure 3.3 (BBC).	Nu uncertainty	1	2	-	3
The participant's preference concerning the two presented visualizations Figure 3.3 (BBC) and Figure 3.4 (IPCC).	Preference for 3.3 (BBC)	2	-	1	3
Negative criticism in regard to Figure 3.3 (BBC).	Missing picutures / icons	-	2	-	2
Negative criticism in regard to Figure 3.3 (BBC).	Positioning of annotations	-	2	-	2
Negative criticism in regard to Figure 3.3 (BBC).	Timeline	-	1	1	2
Positive criticism in regard to Figure 3.4 (IPCC).	Annotations	1	1	-	2
Negative criticism in regard to Figure 3.4 (IPCC).	Complexity	1	1	-	2
The participant's preference concerning the two presented visualizations Figure 3.3 (BBC) and Figure 3.4 (IPCC).	No preference	-	1	1	2
The participant's preference concerning the two presented visualizations Figure 3.3 (BBC) and Figure 3.4 (IPCC).	Preference for 3.4 (IPCC)	2	-	-	2
The participant's assessment of the quality of Figure 3.3 (BBC).	Bad	-	-	1	1
The participant's assessment of the quality of Figure 3.3 (BBC).	Depends on purpose	-	1	-	1
Positive criticism in regard to Figure 3.3 (BBC).	Not overloaded	1	-	-	1
Negative criticism in regard to Figure 3.3 (BBC).	Focus	-	-	1	1
Negative criticism in regard to Figure 3.3 (BBC).	Fonts	-	-	1	1
Negative criticism in regard to Figure 3.3 (BBC).	Subtitle	-	-	1	1
Negative criticism in regard to Figure 3.3 (BBC).	Temperature Scale	1	-	-	1
Negative criticism in regard to Figure 3.3 (BBC).	Too many lines / arrows	-	1	-	1
Positive criticism in regard to Figure 3.4 (IPCC).	Degrees Celcius	-	1	-	1
Positive criticism in regard to Figure 3.4 (IPCC).	Time axis	1	-	-	1
Negative criticism in regard to Figure 3.4 (IPCC).	Colors	-	-	1	1
Negative criticism in regard to Figure 3.4 (IPCC).	Title	-	-	1	1

A. Appendix

EXAMPLE VISUALIZATION PAIR 2 (Figure 3.5 and Figure 3.6)					
TOPIC	**STATEMENT**	**CC**	**SC**	**VIS**	**SUM**
The participant's assessment of the quality of Figure 3.5 (Guardian).	Good	1	3	1	5
The participant's opinion whether Figure 3.5 (Guardian) is easy or difficult for lay people to interpret.	Difficult	2	2	1	5
Positive criticism in regard to Figure 3.5 (Guardian).	Colors	2	2	1	5
The participant's preference concerning the two presented visualizations Figure 3.5 (Guardian) and Figure 3.6 (IPCC).	No preference	1	3	1	5
Negative criticism in regard to Figure 3.5 (Guardian).	Unclear wording / explanations	-	2	2	4
The participant's assessment of the quality of Figure 3.5 (Guardian).	Bad	-	2	-	2
The participant's opinion whether Figure 3.5 (Guardian) is easy or difficult for lay people to interpret.	Easy	-	1	1	2
The participant's assessment of the quality of Figure 3.5 (Guardian).	Medium	-	-	1	1
The participant's opinion whether Figure 3.5 (Guardian) is easy or difficult for lay people to interpret.	Depends on reader	-	-	1	1
Positive criticism in regard to Figure 3.5 (Guardian).	Title	-	-	1	1
Negative criticism in regard to Figure 3.6 (IPCC).	Unclear wording / explanations	-	-	1	1
The participant's preference concerning the two presented visualizations Figure 3.5 (Guardian) and Figure 3.6 (IPCC).	Figure 3.5 (Guardian)	1	-	-	1