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Abstract

Crisis map visualizations have become ubiquitous in news media, presenting crucial information during times of uncertainty. Ensuring accurate comprehension of these visualizations is vital, as misinformation can spread rapidly in crises. To better understand how viewers make sense of crisis map visualizations and to identify potential challenges, two studies were performed. First, a study of online comments was conducted that focused on students' sensemaking processes of 13 visualizations published in the New York Times Series "What's going on in this graph." In the second study, we conducted semi-structured interviews with 18 Digital Natives with different educational backgrounds. This research reveals a multistage process consisting of three interconnected sensemaking activity groups in the comment study: i) first impression, ii) deeper engagement, and iii) personal relation. Four sensemaking activity groups are uncovered in the interview study: i) visual impression, ii) conceptual meaning, iii) deeper engagement, and iv) affective factors. Another key finding in both studies is the significant role of personal connection towards crisis topics since it influences interpretation and understanding. Challenges concerning color concepts, the need for additional context, and the ambiguity of missing data also emerged, affecting viewers' trust and motivation. Our findings suggest that it is essential to address these challenges to enhance the reliability and credibility of crisis map visualizations. This research mainly focuses on Digital Natives' sensemaking processes, warranting further analysis of other lay audience groups. Understanding the interpretation of Digital Natives, as well as their responses to crisis map visualizations, is crucial in effectively conveying critical information in news media.

Kurzfassung

Visualisierungen von thematischen Krisenkarten sind in den Nachrichtenmedien allgegenwärtig und liefern in Zeiten der Unsicherheit wichtige Informationen. Es ist bedeutend, dass diese Visualisierungen genauestens verstanden werden, da viele Fehlinformationen in Krisenzeiten verbreitet werden können. Um ein besseres Verständnis zu erhalten, wie Personen Krisenvisualisierungen verstehen und mögliche auftretende Herausforderungen zu identifizieren, führten wir zwei qualitative Studien durch. In der ersten Studie werden Online-Kommentare der New York Times Series "What's going on in this graph?" aus insgesamt 13 Krisenkarten untersucht. In der zweiten Studie führten wir Interviews mit 18 Digital Natives durch, die jeweils unterschiedliche Bildungshintergründe aufweisen. Die Untersuchung offenbart einen komplexen und miteinander verflochtenen 'Sensemaking-Prozess'. In der Kommentarstudie wurden drei miteinander verbundene 'Sensemaking Activity Groups' identifiziert, während in der Interviewstudie vier solcher Gruppen hervortraten. Ein zentrales Ergebnis dieser Forschung ist die Feststellung, dass der Grad der persönlichen Verbindung zu einem Krisenthema erheblichen Einfluss auf die Interpretationsergebnisse sowie das allgemeine Verständnis der Visualisierung ausübt. Zusätzlich traten Herausforderungen im Zusammenhang mit Farbkonzepten, dem Bedarf an weiterem Kontext und Unsicherheiten bezüglich fehlender Daten auf, welche wiederum das Vertrauen und die Motivation der Betrachtenden beeinflussen. Unsere Forschungsarbeit fokussiert sich primär auf die Untersuchung der Vorgehensweisen von Digital Natives und eröffnet die Notwendigkeit weiterer Analysen in Bezug auf andere Zielgruppen.

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1. Introduction

Crisis visualizations in media play a significant role in informing the general public about various crisis issues, as news media's primary function is to disseminate information to a wide audience [1,2]. A resolution of the Parliamentary Assembly of the Council of Europe outlined the role of the media as one of "the key ways of dealing with and overcoming a crisis" [3, p.2]. They also emphasize that the role of media is especially important in times of crisis in order to be able "to stimulate discussion about the right measures to counter the causes" [3, p.1]. The COVID-19 pandemic, in particular, has highlighted the crucial role of effective crisis communication in the media [4,5]. Maps were used in order to display case numbers and fatalities across various countries and regions. They kept the public informed about the scale and impact of the pandemic. One of the most important online dashboards during the pandemic was provided by the Johns Hopkins Institute, which visualized and tracked reported cases of the virus. It, therefore, allowed live comparison of infection rates among different regions [6]. It proved to be an essential tool in helping the public grasp the full extent of the pandemic's reach [6,7]. In addition to COVID-19, it is evident that the world is facing an increasing number of other critical and urgent challenges. Issues such as inflation, climate change, political tensions, and humanitarian crises are just some to name. These problems have global effects, and addressing them requires an understanding of the geographical impact and the scope of the situation [8]. Research has demonstrated the utility of data visualizations in aiding the general public in understanding crisis issues [2,9,10,11,12,13,14]. Map visualizations, in particular, are said to be more engaging and memorable compared to text [2,11,15,16,17,18]. Yet, it remains uncertain which visualization types are the most informative, favored, and suitable for conveying crisis information [19,20].

The underlying complex and ever-changing nature of crisis topic visualizations can be hard to create from the designer's perspective and difficult to read from the user's perspective [21,22]. Historical studies, like Handmer's [23], have evidenced people's misinterpretation of hazard maps because of unsuitable cartographic design choices [24,25,26]. In addition, users' varying level of background information and map literacy can influence their comprehension of the provided information [27]. Furthermore, the complex nature of crisis topics can make it hard to understand the map's message. The reasons are that users felt that they could not trust official sources, be overly confident about interpreting the map, or experience strong emotions such as fear, uncertainty, depression, and anxiety [28,29,30]. All these factors may hinder the comprehension of crisis-related visualizations. The situation becomes more intricate with the occurrence of conflicting or rapidly changing news during crises [21]. Given the potential consequences of misinformation and miscommunication during a crisis, the importance of meaningful crisis maps has reached a significant magnitude [31]. The Parliamentary Assembly of the Council

1. Introduction

of Europe outlined that “the risk of online disinformation, polarisation, and populism increases in times of crisis” [3, p.1]. Major crisis events often capture attention in the news, typically prompting dramatic statements regarding the associated risks [32,33,34]. In the context of climate change and the COVID-19 pandemic, misinformation and manipulative news are prevalent on the internet, often supported by visualizations, including maps, as a means of persuasion [32,33]. The term ‘infodemic’ is utilized in both popular media and academic discussions and is used to convey the idea of an abundance of ‘fake news’ and conspiracy theories. These conspiracy theories and misinformation, often disguised as fake news, can spread widely in online news outlets and social media, creating an environment in which large amounts of misleading or false information is quickly spread. The term highlights the scale and impact of misinformation in the digital age [35,36]. It has the potential to influence people’s behaviors and attitudes, consequently shaping the course of the crises. [2,37].

According to Muehlenhaus [38] with the widespread dissemination of maps on online platforms, there is an increased need to educate map readers to be critical consumers of visual media. It is, therefore, essential that map visualizations used in news outlets are not only accurate but also comprehensive and clearly conveyed to build trust and facilitate understanding [15]. Moreover, the Digital Native generation, born into a digital era [39], holds influential positions in sharing and consuming information online [40,41]. It is of particular importance for Digital Natives to comprehend crisis-related maps as they belong to a generation that has grown up with technology and digital media, thereby being more inclined to rely on online sources for information [42]. Owing to their frequent exposure to digital platforms, Digital Natives are more likely to encounter and interact with crisis-related maps online, making it imperative that they possess the ability to interpret and utilize these visualizations to make informed decisions in crisis situations [40,43,44].

We, therefore, investigate the following research question: "What are Digital Natives’ cognitive sensemaking activities and the associated challenges when they try to comprehend maps of crisis issues in popular news media?".

To gain a deeper understanding of occurring sensemaking activities and the challenges Digital Natives face when interpreting visualizations, so we conducted two qualitative studies. The first study analyzes online discussion comments published in the New York Times Series “What’s going on in this graph?”¹. The series aims to increase the statistical literacy of students, particularly high school students, by encouraging them to engage with visualizations from various contexts in a meaningful way. They invite readers to observe and question the shown visualizations and to reflect on potential impacts on their communities. Created in partnership with the American Statistical Association (A.S.A.)², the program includes a succinct questionnaire to solicit students’ feedback on the graphs, with A.S.A. professionals responding to their comments in the discussion

¹<https://www.nytimes.com/column/whats-going-on-in-this-graph>

²<https://www.amstat.org>

forum. The graphics utilized in this series are not specifically tailored toward younger audiences but instead apply to the newspaper's traditional readership. These graphics can also be found in other articles featured in the publication. Furthermore, a comprehensive explanation of the graph and its mathematical and statistical attributes is provided one week following its publication. Maps are also used frequently and extensively in this series, with crisis-related topics being addressed in many cases. The focus of the topics is climate change issues, COVID-19-related topics, and political, economic, and social crises. These topics have a high popularity among the participating students and registered many comments. Accordingly, we analyzed 13 crisis maps in detail to find out which sensemaking activities arise and which challenges students face while they engage with maps depicting data. In a subsequent study, we conduct interviews with 18 Digital Natives focusing on three of the previous 13 maps in more detail. We aimed to speak to Digital Natives with different educational backgrounds.

Contributions This research has been carried out by the author under supervision. The results strive to uncover cognitive sensemaking activities and challenges faced by Digital Natives while understanding crisis maps in news media. Key implications include a multistage process consisting of three interconnected sensemaking activity groups in the comment study: first impression, deeper engagement, and personal connection, and four in the interview study: visual impression, conceptual meaning, deeper engagement, and affective factors. Another key finding is the significant role of personal connection towards crisis topics since it influences interpretation and understanding. Challenges concerning color concepts, the need for additional context, and the ambiguity of missing data also emerged, affecting viewers' trust and motivation. Our findings suggest that it is essential to address these challenges to enhance the reliability and credibility of crisis map visualizations. The results could contribute to raising awareness of how crisis maps are perceived and subsequently provide thought-provoking impulses to the quality of news media content. By considering the outlined challenges, journalists and map designers can create crisis maps that effectively convey critical information to the public. This research mainly focuses on Digital Natives' sensemaking processes, warranting further analysis of other lay audience groups.

2. Research Background

In this section, we will use the terms 'graphs', 'data visualizations', and 'visualizations' interchangeably. Graphs have long been recognized as powerful tools for conveying quantitative information, owing to their perceived ability to enhance understanding [24,25,26]. Nonetheless, the process of sensemaking with graphs is far from straightforward [45,46]. It is influenced by the specific domain and the characteristics of the data being presented [27]. The field of understanding data and visualizations has been the subject of research, with numerous studies dedicated to exploring how individuals engage in the process of sensemaking. In the upcoming section, we will delve into these studies, examining the diverse range of theories and frameworks that shed light on these complex cognitive processes. Moreover, we will conduct a thorough review of the existing literature on sensemaking in the context of crisis visualizations. By synthesizing the wealth of insights collected from these studies, our aim is to present an informed understanding of the significance of sensemaking within the domain of crisis visualizations.

2.1. Data-centric sensemaking

Sensemaking is a multifaceted concept explored across diverse academic fields, including human-computer interaction [47], psychology [48], organizational settings [49], and information seeking [50]. It refers to the cognitive process of extracting meaning from information into a coherent conceptual representation. In the domains of information science and human-computer interaction, sensemaking is recognized as an iterative and dynamic process that transforms raw data into meaningful insights. Scholars such as Blandford and Attfield [51] define sensemaking as the active creation of meaning from information, whereas Hearst [52] and Russell [53] highlight its essence in connecting different pieces of information to form a unified conceptual framework. The notion of data frame theories, exemplified by Klein et al. [48], emphasizes how individuals' existing mental models or frames influence the perception, interpretation, and assimilation of new data. Through interactions with the data, these preexisting frames may undergo adjustments or reinforcement, reflecting an integral aspect of the sensemaking process [54]. Overall, sensemaking entails a complex set of activities, including searching, filtering, organizing, creating mental structures, and constructing evidence, all aimed at comprehending difficult scenarios effectively. In a study conducted by Koesten et al. [55], data-centric sensemaking behaviors were investigated, resulting in the identification of "three clusters of sensemaking activities: Inspecting data, engaging with data content more deeply, and placing data within broader contexts" [55, p.2]. These findings contribute to a deeper understanding of how individuals engage with and derive insights from data.

2. Research Background

2.1.1. Graph-based sensemaking

Koesten et al.'s [55] study focused on data sets, while other frameworks centered on graph-based visualizations also propose that sensemaking occurs at three interconnected and incremental levels [56,57,58,59]. Making sense of data visualizations at the elementary level is dependent on recognizing the depicted visual properties. This can significantly impact the viewer's ability to understand graphical information efficiently [56,60]. The intermediate level focuses on translating visual features into conceptual meaning [59,61]. This process entails interpreting visual elements as a whole and forming a specific concept, such as perceiving a downward pointing line as a decelerating trend [58]. If a visual element doesn't inherently trigger a particular fact or relationship, researchers have discovered that understanding the information becomes more difficult [25,59,61,62,63,64,65]. Additionally, Glazer et al. [66] emphasize the importance of map literacy in obtaining meaning from graphs, suggesting that it plays a crucial role in understanding map elements. The third level pertains to the influence of existing knowledge and expectations of content, which can impact participants' interpretations of graphs [64,67]. Mistakes in interpreting visualizations may arise when the visual encoding fails to intuitively convey the data and relevant relationships [67,68].

2.1.2. Sensemaking of map visualizations

Previous research has predominantly focused on the comprehension of tables and statistical graphs, leaving a significant gap in our understanding of how maps are interpreted, understood, and read. While maps have been recognized as powerful tools for presenting spatial data [69,70,71,72], there is limited literature addressing the specific challenges and processes involved in comprehending them. Existing studies have drawn upon the three-process visualization comprehension theory, which emphasizes the recognition of visual features, the understanding of relationships among visual features, and the integration of contextual elements within maps [73,74,75]. However, further research has expanded upon this theory to account for additional steps that vary depending on the type of visualizations being examined. Lee et al. [15] have suggested that the three-process theory of visualization comprehension might oversimplify the cognitive processes involved and does not adequately address basic comprehension tasks with unfamiliar or unknown visualization types by inexperienced users. In a study conducted by Fan et al. [60], the three-process visualization comprehension theory was validated in the context of older adults making sense of interactive COVID-19 visualizations. The findings suggested that the theory should be further extended to incorporate an additional step, namely 'Error-Recovery,' which accounts for the strategies individuals employ to correct their misunderstandings or misconceptions when engaging with complex visualizations.

2.1.3. Challenges

The comprehension of data visualizations, such as graphs and maps, presents a significant challenge for viewers, leading to difficulties in analyzing, interpreting, and effectively

2.2. Sensemaking of crisis map visualizations in news media

utilizing the information they convey [27, 64, 76]. This complexity can be attributed to several interrelated factors, making the process of understanding visual data multifaceted. One prominent factor contributing to the challenges faced by viewers is insufficient instruction and, hence, the literacy of how to read maps [76, 77, 78, 79]. In educational settings, for example, students may receive limited guidance on how to extract meaningful insights from graphs or maps. The absence of explicit instruction on decoding various elements, such as axes, scales, and labels, may hinder their ability to make sense of the presented data accurately. Moreover, viewers' prior knowledge and familiarity with the subject matter play a crucial role in comprehending data visualizations [27, 60]. When individuals possess limited background knowledge in a particular domain or lack familiarity with the content being presented, they may encounter difficulties in fully grasping the meaning and implications of the visualized information [80, 81, 82, 83]. Additionally, the cognitive load imposed by intricate data visualizations can overwhelm viewers, further complicating their understanding. Visualizations with a high level of complexity, incorporating numerous data points or complex visual elements, can tax the viewer's cognitive resources, making it challenging to process and retain information [15, 67]. Consequently, viewers may encounter difficulty making connections, drawing accurate inferences, and contextualizing the information within a broader framework. These challenges can limit the potential for data visualizations to effectively communicate insights and impact decision-making processes.

2.2. Sensemaking of crisis map visualizations in news media

Zhang et al. [2] "define crisis visualizations as visual representations of information about undesirable situations that posit threats to human beings" [2, p.2]. These visualizations communicate complex crisis-related information, "such as disease prevalence, epidemiological simulations, and economic and social changes" [2, p.2]. The purpose of crisis visualizations is to provide stakeholders, including emergency responders, policymakers, and the public, with insights into the nature and scale of a crisis, facilitate trend and pattern identification, and support informed decision-making [72]. Crisis visualizations discussed in literature can be parted into two different fields: graphics used for emergency response or information purposes. Emergency response maps target experts and niche audiences and prepare stakeholders to take immediate action [84, 85]. Whereas, 'information maps' focus on informing the general public. They are often provided by media outlets, institutions, and private map designers [46, 86, 87].

2.2.1. Perception of crisis map visualizations

It is important to design crisis visualizations responsibly due to the sensitive nature of the communicated data. Research has examined various aspects of crisis visualization design, including guidance on effective risk map design [2, 46, 60, 71, 72, 88, 89]. Key properties of crisis maps, such as color, size, shape, and geometry, influence how readers perceive and understand the information [2, 15, 46, 90]. Since map reading is a complex process [84],

2. Research Background

several studies have assessed the effectiveness of map properties and their impact on risk perception, comprehension, and individual preferences [2, 46, 84, 91, 92]. Fang et al. [46] examined the impact of differing map formats and color combinations on viewers' comprehension of COVID-19 maps by employing eye-tracking measurements. They found that warm color tones are more effective in visual cognition and understanding compared to cool or mixed color tones. They also concluded that choropleth maps are effective in expressing risks. Another study by Cheong et al. [93] found that different cartographic representations of risk can influence readers' decision-making.

2.2.2. Sensemaking of crisis map visualizations published in news media

The accessibility and comprehension of crisis maps have become increasingly important in the media landscape. Various media channels, including news outlets and social media platforms, play a critical role in distributing crisis maps to a broad audience. These maps provide real-time information, raise awareness, and engage the public in understanding and making sense of the crisis [94, 95, 96, 97, 98, 99]. Researchers examined the power of visualizations, including maps in media [8, 70, 87, 100]. They highlight the significance of recognizing the potential misleading traits that maps can possess since they have an influence on trust and decision-making. However, cartographers can play a role in averting misinterpretation by exploring methods to craft map elements in a more transparent manner [101]. This is especially important for crisis maps since they are increasingly utilized as collective sensemaking tools as technology and, therefore, social media platforms continue to advance [100]. Researchers found that it is essential to acknowledge that online discussions and dissemination of crisis maps can also contribute to the spread of rumors and misinformation [1, 45, 102]. Lisnic et al. [1] conducted a study analyzing Twitter comments related to crisis maps and found that accurately depicted data visualizations can unintentionally support online misinformation when presented without proper context. Other studies have similarly indicated that a lack of context in crisis visualizations can lead to significant misinterpretations [103, 104, 105] fueled by fear, unreliable sources, and personal associations [103]. Building on these findings, Muehlenhaus [38] argues that the ease of sharing maps through social media platforms highlights the importance of educating map readers to become critical consumers of visual media. We, therefore, want to emphasize the significance of understanding the sensemaking process and the potential challenges associated with the dissemination and interpretation of crisis maps in the media landscape.

2.2.3. One size fits all?

Research conducted previously has examined crisis visualizations of past epidemics [2, 46, 60, 100, 106] alongside emergency scenarios such as natural disasters [84, 107], social crises [108, 109], and financial crises [110]. Further studies have focused on tools and simulation possibilities [85, 111], as well as the perception of risks from crisis visualizations [84]. These studies target experts in niche industries responsible for creating emergency maps. Interpretation of these maps demands higher visual data literacy skills [112].

2.2. Sensemaking of crisis map visualizations in news media

However, there is less research addressing crisis maps, which are designed to inform a broader audience [2]. Nowadays, crisis communication often involves a mutual exchange of information between the public, the media, and the government. This means that people not only receive information but can also respond to and share it. This shift requires taking into account the needs and values of all stakeholder groups involved [2]. Given that the audiences are diverse, ranging from the general public to specialists, Kostelnick et al. [85] argue that crisis maps need to take several factors into account. In particular, it is essential to address the attributes of users, the tasks they are engaged in, and the inherent characteristics of the risks involved. This highlights the need for a comprehensive approach that takes into account both the human elements (users and tasks) and the intrinsic attributes of the risks being mapped. In their study, they suggest a framework for creating maps that illustrate sea level rise, especially for an audience with varied levels of expertise in the subject and map reading. They argue that designing maps for individuals with different levels of knowledge about the topic and map-reading skills is a complex challenge that requires further investigation [85].

In our study, we want to target one specific group of the general public: Digital Natives. The term Digital Native attributes to a generation that is born after 1980 and pronounced to use new technology. [39,113]. These new technologies accompanied Digital Natives already while they were growing up. It therefore influenced their ways to learn [39,114,115,116]. Prensky [39] emphasized that Digital Natives are processing information very fast, showing a clear preference for graphics over text. This inclination towards visualizations plays a vital role in how Digital Natives process information. Despite this aspect, there has been limited research addressing how Digital Natives make sense of visualizations, particularly in the context of crisis maps.

Prior studies have highlighted the importance of enhancing crisis maps [2,46,60,72,84,85]. However, research analyzing the perception of crisis map visualizations in terms of user cognition has been limited. [72]. Crisis visualizations presented in news outlets have garnered significant public involvement [2]. It is necessary to represent crisis information thoroughly. Therefore, our objective is to uncover emerging trends and challenges of Digital Natives in understanding crisis map visualizations.

3. Comment Study

In order to investigate how Digital Natives make sense of crisis maps, this study utilizes a qualitative analysis of comments published in the New York Times Series “What’s Going on in this Graph?”¹. Comments can provide valuable insights into peoples’ comprehension of crisis visualizations, as people may feel less observed and, therefore, respond more truthfully. Our sample focused on 13 map visualizations depicting a diverse spectrum of crisis topics, discussing subjects of COVID-19, Climate Change, and economic crises.

3.1. Methodology comment study

The New York Times provides critical news on a daily basis. The outlet features content on serious crisis topics, often utilizing map visualizations in order to demonstrate the geographical extent of the crisis. Given the widespread popularity of the New York Times as a media outlet, incorporating the content of the series into our research is beneficial for the following reasons:

- We aim to target map visualizations only, meaning that no additional information sources should accompany the maps. This is given in a series featured by the New York Times called “What’s going on in this graph?”. The series is a regular feature that presents graphics published previously in articles online. In this series the maps are presented without any associated context, as for example a headline or other textual descriptions.
- The series presents a variety of graphs on different crisis topics.
- The series invites students to share their observations, analysis, and interpretations of the graph, intended to train their map literacy.
- The graphics often generate discussion and commentary from readers, providing valuable insight into how crisis visualizations are perceived and interpreted by this group of readers.

¹The New York Times collaborates with the American Statistical Association (A.S.A.) in an ongoing weekly series called "What’s Going On in This Graph?". This feature presents visualizations from The New York Times and encourages students to engage in online discussions where they analyze and interpret these visuals. This educational initiative has been running for the past six years, promoting data literacy and critical thinking among students. The homepage can be found under this link: <https://www.nytimes.com/column/whats-going-on-in-this-graph>

3. *Comment Study*

3.1.1. Study design

The series targets primarily high school students over 13 years old in the USA. High school teachers use this format in their classes and have their students comment on the maps online. However, the open format of the comments allows anyone to participate in the discussion. Therefore, English-speaking participants from other countries also commented on the visualizations. The participant's location and their chosen user name can be seen in the online comments. It is common for students to provide their first name or a made-up name as identification and the name of their representative high school as their location. Given that several hundreds of comments were posted for each visualization, each varying in quality, we established specific criteria for the comment selection. These criteria are designed to identify the most suitable comments for our analysis:

- Comments were required to consist of at least 100 words to ensure the quality of the comments. This requirement aimed to prevent short-formulated comments, as they could not provide sufficient material for subsequent analysis.
- Comments were expected to have been posted prior to the 'reveal session,' in which experts provide detailed explanations of the statistics and background information related to the map. Typically, the 'reveal session' occurs approximately one week after visualizations are initially published in the series.
- Additionally, precautions were taken to mitigate location bias. Therefore, if possible, each location or institution was included only once in the analysis per appearing visualization.

These criteria are implemented to mitigate data bias and guarantee the overall quality of the analysis. The comments were retrieved in December 2022 using a self-written python script and a selenium python crawler. The corresponding code can be accessed via the provided Gitlab link².

Visualizations The series comprises over 119 visualizations (published until 29 September 2022), each covering various types and topics. Notably, 27 of these visualizations fall into Munzners' category of maps [69]. A list of all 119 visualizations and the 27 maps, their characteristics, and statistical insights can be found in the appendix (A.1). This research specifically focuses on maps illustrating crisis situations. We relied on the definition proposed by Zhang et al. to identify suitable crisis visualizations [2]. In their research they define "crisis visualizations as visual representations of information concerning undesirable situations that pose threats to human beings. These visualizations effectively communicate information such as disease prevalence, epidemiological simulations, and economic and social changes" [2, p.2]. Based on this definition, we selected a total of 13 map visualizations for the commentary study. These visualizations were divided into four

²https://git01lab.cs.univie.ac.at/sandramars96/vis_master_thesis.git

different types of maps according to Munzner’s categorization: divergently ordered color maps, sequentially ordered color maps, categorical color maps, and proportional symbol maps [69]. The number of comments per item varied from 117 to 1003. A list of the map and their characteristics, as well as their links, can be found in the appendix (A.2). The data we used can be freely accessed through the provided links. Due to data permission rights, we are not allowed to publish any visualizations as part of this thesis.

3.1.2. Analysis procedure

The majority of the comments were structured around a set of questions [117] elaborated in collaboration with the American Statistical Association (A.S.A.)³. They were designed to encourage commenters to engage in deeper reflection on the map and its contextual significance. The provided questions [117] are meant to be answered in the following order:

1. What do you notice?
2. What do you wonder?
3. How does this map relate to you and the society you live in?
4. What’s going on in this graph? Create a catchy headline that captures the graph’s main idea.

The comments were transcribed and subsequently analyzed using Atlas.ti, a qualitative data analysis software. The codes were derived through a systematic review of the collected comments, identifying recurring themes and patterns. Axial coding was then applied to the comments in order to group the codes into themes that represented various sensemaking activities (informed by Strauss and Corbin [118]). The codes were further categorized into three sensemaking process activities: i) first impression, ii) deeper engagement, and iii) personal relation. A total of 45 codes emerged from the analysis. The comments underwent a second round of analysis to confirm the assignment of the previously established codes. Saturation of the data was achieved with a range of 20 to 25 comments per visualization, indicating that a comprehensive range of perspectives had been captured. It is worth noting that quantifying the results would be misleading since multiple individuals or even entire groups may have contributed to a single comment. The codebook can be found in Section A.5. It supplies a list of all used codes, their description and corresponding example quotes.

³<https://www.amstat.org>

3. Comment Study

3.2. Results of the comment study

Our qualitative analysis revealed three sensemaking activity groups: first impression, deeper engagement and personal relation to the map. In the upcoming sections we will explore these emerging themes in detail. Since we believe quantifying our results is not meaningful, we refer the depicted quotes only to the visualizations, abbreviated with ‘VIS’ and their respective number. An overview of the ‘VIS’ abbreviations and the visualizations they refer to can be found in section A.2.

3.2.1. First impression

The first impression phase refers to the initial reactions and perceptions that individuals in our sample had upon viewing the graphic for the first time.

“First of all, I have the feeling that it is a lot, and it looks so messy at first, with all the red circles.” – VIS1

In many instances, participants expressed their immediate associations or noteworthy map elements that caught their attention: They let the map take effect. In other cases, participants quickly detected patterns and trends within the graphic.

3.2.1.1. Let the data take effect

In their comments, participants sometimes exhibit a tendency to provide a brief introduction to the map and its topic before delving into deeper analysis. This introductory approach allows participants to identify and discuss map-related features, such as the representation of colors and their distribution on the map. In addition, participants may include further associations in their introductory sentences, such as the relevance of the crisis or their personal opinions about the map.

“The map immediately acknowledges a problem, one that needs to be addressed and figured out soon.” – VIS9

Participants also may attribute facts to the graphic that are not actually part of the visualization but rather stem from their own preconceived thoughts about the depicted topic. These perceived facts are mistakenly treated as true and can subsequently influence further analyses. Sometimes participants are challenged with maps that visualize probabilities or future predictions.

“What do I notice? In about 29 years, wind and solar power will become one of the main ways of creating and supplying energy all across the country.” – VIS4

“I notice how the United States is going to increase its wind and solar footprint by a lot by 2050.” – VIS4

They often perceive them as concrete realities rather than representations of planned or potential events.

3.2.1.2. Patterns and trends

The majority of participants describe patterns and trends as their initial impression of the graphic. They examine the trends and patterns that appear on the map or between different maps, often grouping items, analyzing their spatial distribution, and comparing results across different charts and variables, particularly when multiple ones are available. Based on the observed trends, participants occasionally draw conclusions and attempt to derive explanations at first glance.

“What we first noticed was that the colder temperatures mostly occurred in the midwest [,] being mostly [in] Texas, Nebraska, Arkansas, and Kansas. We also noticed the hot temperatures occurred mostly in the northwestern side.” – VIS3

In certain map concepts, participants faced challenges in accurately identifying patterns and trends. For instance, in VIS5, which employed a divergent ordered color map:

“From 1991-2020 [,] there is lots of precipitation up north and in the middle. There are also dry spots in the southwestern area [,] so I wonder how the lack of precipitation affects them since their area isn’t very blue” – VIS5

Here, participants mistakenly interpreted negative growth of the variable as having the opposite meaning. As a result, the decrease in ‘precipitation’ was often confused with ‘drought’.

3.2.2. Deeper engagement

In the next phase, participants engage in a more rigorous analysis. They immerse deeper into the underlying causes as well as impacts of the crisis and considering its potential effects. Individuals use their prior knowledge to draw additional conclusions that may not be explicitly shown on the map. Depending on the type of map, intensity of the interaction varies. Also, challenges did arise while participants made further sense of the map.

3.2.2.1. Outline causes and impacts of the crisis

The second question of the series asks participants what exactly they wonder about. Depending on the type of map, participants were often curious about how the crisis was caused. They outline the results and how they are distributed:

- **Most expressive data aggregations or categories:** Wonder about the causes of the most outstanding values in the form of clusters, state, country, or celestial directions.

“I wonder why most of the heat records were made in Oregon and Washington State.” – VIS3

3. Comment Study

- **Distribution of the measured variable:** Participants see the map as a whole and compare the distribution of the variable between depicted areas.

“I wonder how the West side of the country is less polluted.” – VIS 8

- **Differences between maps, if several were shown:**

“I wonder why precipitation had a major increase over the last thirty years?” – VIS 5

- **Differences between variables if more than one is used:**

“I do wonder why wind footprint is used much more compared to the solar footprint.” – VIS 4

- **Outliers and non-values:**

“I also wonder why states like North Dakota and Wyoming were outliers in the first map titled: Congress should do more.” – VIS1

As a subsequent thought, participants usually answer their wonderings by making assumptions and conclusions about how the crisis might have arisen. They rely on their own contextual and prior knowledge to make these inferences.

“It is interesting how the concentration in the middle of the US is where the most footprint is going to be? It is also understandable because of how little the population is in those areas.” – VIS 4

In rare cases, participants reconsidered their conclusions when they realized that they could not be applied to the entire graph. In such cases, new and more appropriate ideas were developed for areas or items that could not be explained by the original conclusion.

“Those states have the big populations than others so that could be a factor of why the deaths are high. But for example Texas has a lighter color although its big population. A likely reason why states like these [,] which have huge populations [,] are on the lighter side may be because of the amount of factories there are.” – VIS8

Participants often reflected on the results of the crisis, including its impacts and global effects. They often derive causes and discuss possible future scenarios, mentioning empathetic thoughts:

“I wonder how the countries that are in the red are feeling right now, I could never imagine what is going through their minds.” – VIS11

Throughout the whole stage of outlining the causes and impacts of the underlying crisis, participants focus deeply on colors (saturation and hues) by using them as a reference:

California is the darkest in all 3 maps and that means that it shows that California wants officials to do something about it heavily. – VIS1

Depending on the type of map and the crisis topic, participants engaged with the map to varying degrees of intensity. Participants showed particular interest in maps that depict changes over different periods of time, as seen in VIS5 and VIS6. Here, they wondered about the reasons for the observed changes.

3.2.2.2. Challenges

If challenges or misinterpretations of map concepts occurred during the initial impression of the graphic, they often went unnoticed and subsequently influenced deeper analyses. This also lead to further challenges and misinterpretations.

During the phase of deeper analysis, participants also expressed their wonderings about the map, as they posed numerous questions regarding the displayed data:

- They questioned the completeness of the map, outlining that certain states or regions were not included:

“After looking at the map I start to realize there’s no wetland nor coast on the map, I wonder why it was not shown.” – VIS12

- There was confusion regarding the meaning of several map elements. In this example, the participant refers to the fact that rising sea levels are not depicted on the map, although it has been depicted on the map, but the chosen color did not stand out enough:

“I wonder why, even though “Sea level rise” is a major issue due to concerns such as the Arctic, and is part of the legend in this map, there is no distinguishable area shown to be affected by it.” – VIS7

- Participants inquired about possible correlations of measured variables:

“Are there relationships between risks? For example, if there is flooding, does that mean that there might be sea level rising?” – VIS 7

- They wondered about the exact meaning of the measured variable:

“I wonder what exactly plant hardiness means.” – VIS6

- They wondered how the dataset was calculated:

“I wonder how this graph was made. How did the researchers come up with the needed power for 2050, and how did they decide where the power would come from?” – VIS4

Additional challenges arose as participants frequently referenced facts that were not present on the map. At times, individuals compared the results presented in a graph with their existing knowledge, assuming that the information they expected to find was depicted on the graph, even if it was not actually there. They may have projected their expectations onto the graph and made comparisons based on those assumptions.

3. Comment Study

"What I've noticed is that there are more Covid-19 cases by the day, than there was when it had barley started." – VIS10

Another frequent challenge observed in the data was drifting off the topic. Participants frequently became sidetracked from the content when it came to popular topics like COVID-19 or global water stress. They would sometimes react emotionally toward the visualization or allow their personal opinions and biases to take precedence.

"What do you notice? Most of the pollution is caused by fuel for power generation, transportation, and commercial things. Also we aren't stopping anything, people just want to beli[e]ve its not their fault by doing the 3 R's but the world will never b[e] the same since the industrial revolution. Like back then we ruined the earth AND the future earth. Like I'm sorry but this is mine and yours and everyone's burden to bear, WE ARE HURTING THE EARTH!!!!!" – VIS8

This tendency often impeded their ability to objectively analyze the presented data and draw well-informed conclusions.

3.2.3. Personal relation to the map

Participants also tend to establish a personal connection with the map, outlining their personal message, expressing motivational thoughts, and assessing their own level of risk.

Participants contemplate the potential impact of the crisis graphic on themselves and their immediate surroundings. Some participants recognize the graphic's purpose of raising their awareness about the crisis.

"We believe graphs like these are absolutely vital to maintaining good health. With this graph, we can learn more about our community's air quality and learn about other places where we could possibly live in order to avoid death caused by air pollution." – VIS 8

In rare cases, participants perceive the message as irrelevant to their own lives, assuming it is intended for someone else. Furthermore, participants engage with the call to take action in response to the crisis. They ponder the question of responsibility, considering who should resolve the crisis, and reflect on their own potential contributions.

"I wonder what is being done to mitigate these climate risks around the world?" – VIS 7

"I want to help!" – VIS 9

In addition, participants evaluate their personal risk.

3.2. Results of the comment study

"This relates to me and my community because it affected everyone around me not only everyone but a lot of things were damaged from the heat and I was worried about people who don't have the advantage of an AC or something to keep them cooled off." – VIS 3

They often indicate the risk of their place of residence and share their own experiences in dealing with the crisis.

4. Interview Study

To get a profound understanding of our research question, we initially collected and analyzed data in the form of comments, as described in Section 3. Now, to delve deeper, we conducted 18 interviews with 'Digital Natives'. A Digital Native (see 2.2.3) refers to a person who has been exposed to and familiar with digital technologies, such as mobile devices, the internet, and computers, from a young age [39]. We specifically selected individuals with diverse educational backgrounds and expertise levels, aiming to avoid bias.

4.1. Methodology interview study

In our second study, we invited 18 participants to make sense of three map visualizations, which have also been utilized for the comment study. The selection process of the visualization is explained in detail in the upcoming section 4.1.2. Interviews were conducted in May and June 2023 via Zoom. The study received ethical approval from the University of Vienna's ethics committee under reference number 0093. The ethics submission can be found in Section A.3.

4.1.1. Participants

We aimed to address Digital Natives of diverse educational backgrounds and different fields of profession and study to have a broad understanding of the general public. Participants were recruited through an open call disseminated across prominent social media platforms, namely Instagram and Facebook. Additionally, the extended social network of our research group was leveraged to reach out to potential participants. Inclusion criteria necessitated proficiency in either English or German, an age range between 18 and 28 years, and a willingness to partake in recorded interviews. Participants were not remunerated for their involvement. Data saturation occurred with a number of 18 participants and is similar to other studies [119,120]. The majority of participants were from Germany and Austria, one participant was from France. During the course of two interviews, minor disruptions in internet connectivity were encountered, which did not interrupt the interview substantially but simply prolonged the conversation slightly. The sampled participants represented a diverse array of professions, encompassing a landscape gardener, a breath work therapist, a marketing manager, and other diverse fields of study and profession. An overview of the participants' respective professions and educational backgrounds is detailed in Figure 4.1.1. Prior to the interviews, all participants provided written informed consent. The participant information sheet, elucidating the study's aims and protocols, alongside the informed consent form, is located in Section A.4.

4. Interview Study

Location	Number of participants
Wien, Austria	3
Steiermark, Austria	3
NRW, Germany	2
Bavaria, Germany	8
Baden Wurtemberg, Germany	1
Bas-Rhin, France	1
total number of participants	18

Educational background	Number of participants
Certificate of secondary education	3
High school graduation	6
Apprenticeship	5
Bachelor	1
Master	3
total number of participants	18

Field of occupation/study	Number of participants
cultural/creative sector	5
craft/industrial sector	5
health sector	2
academical sector	2
civil sector	2
unemployed	1
student	1
total number of participants	18

4.1.2. Example visualizations

In the interview study, we carefully handpicked three map visualizations from the pool of 13 visualizations utilized in the comment study. We outlined the following selection criteria:

- The visualizations should represent three different types of maps (proportional symbol map, divergent and sequential choropleth map) and address distinct crisis topics (COVID-19, Climate Change, and economic crises). By adopting this approach, we aimed to encompass a wide range of themes and map types, mitigating potential biases associated with specific topics or map categories.
- Furthermore, we chose visualizations that posed considerable challenges during the comment study, making them particularly relevant for further exploration in the interview study.

Due to legal restrictions, we are unable to include the original visualizations directly in this thesis. However, the maps can be accessed through the provided links (see next page) on the New York Times website.

Also we included sketches mirroring the original visualizations for a better understanding. For ease of reading and reference, we will simplify the visualizations by using the abbreviations VIS1, VIS2, and VIS3. The three visualizations and their respective features are detailed on the next pages.

- **Visualization 1**, referred to as **VIS1**, focuses on the COVID-19 crisis. It presents a proportional symbol map showcasing the absolute number of COVID-19 cases in the United States during the year 2020. The visualization employs magnifying, red-transparent circles to represent the number of cases in each respective governmental district. The map is further organized by states, with clear labels for each state provided. This graphic was published on September 10, 2020, and has garnered a total of 385 comments as of that date. The original visualization is available at the following link: VIS1¹. Figure 4.1 depicts a self-drawn version mirroring the respective visualization.
- **Visualization 2**, referred to as **VIS2**, addresses the issue of water stress on a global scale. This visualization takes the form of a sequential ordered choropleth map featuring a color gradient ranging from light yellow to deep red to represent different levels of water stress. Additionally, gray fields are used to indicate missing data in certain areas. The map is organized by countries, and specific cities and countries are marked to provide additional context. Published on January 16, 2020, VIS2 has garnered 160 comments up to the current date. The visualization is available at the following link: VIS2². Figure 4.2 depicts a self-drawn version mirroring the respective visualization.
- **Visualization 3**, referred to as **VIS3**, focuses on the demographic crisis in the USA. It presents the percentage change in the working-age population using a divergently ordered choropleth map. The map employs different shades of purple and orange to indicate varying levels of change. Organized by government county, the visualization does not include any additional labels. Published on September 26, 2019, VIS3 has received a total of 544 comments to date. As with the previous visualizations, we are unable to directly display VIS3 in this paper due to legal restrictions. The visualization is available at the following link: VIS3³. Figure 4.3 depicts a self-drawn version mirroring the respective visualization.

¹<https://www.nytimes.com/2020/09/10/learning/whats-going-on-in-this-graph-covid-19-cases-in-america.html>

²<https://www.nytimes.com/2020/01/16/learning/whats-going-on-in-this-graph-global-water-stress-levels.html>

³<https://www.nytimes.com/2019/09/19/learning/whats-going-on-in-this-graph-sept-25-2019.html>

4. Interview Study

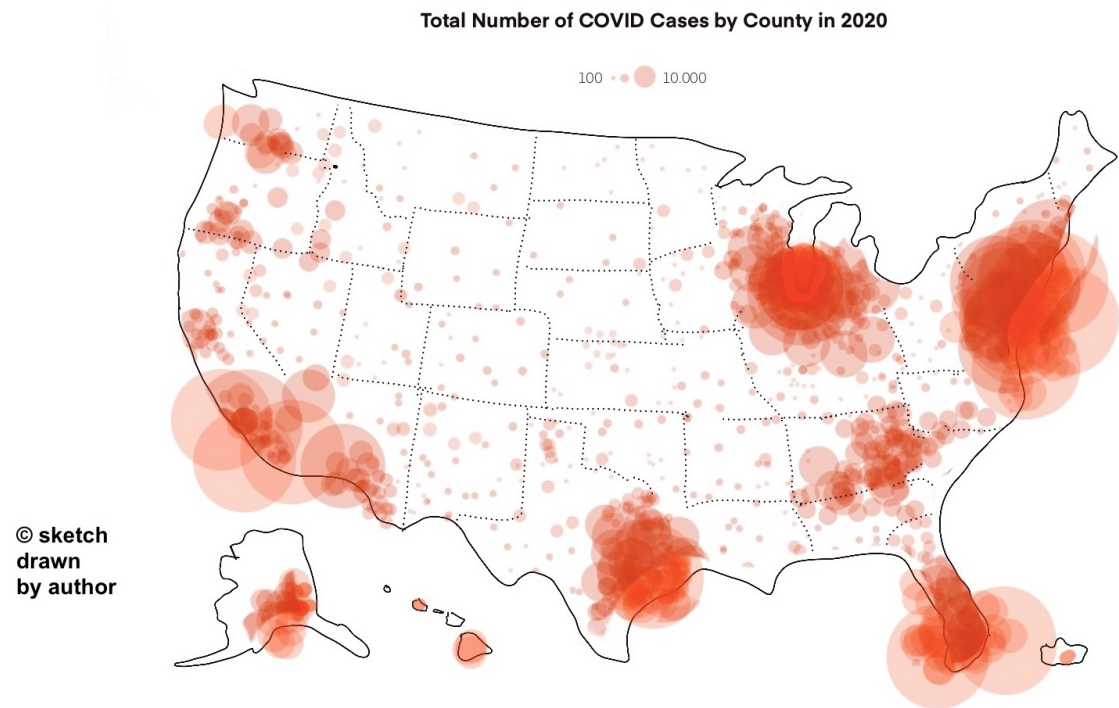


Figure 4.1.: Visualization 1: A sketch drawn by the author

4.1. Methodology interview study

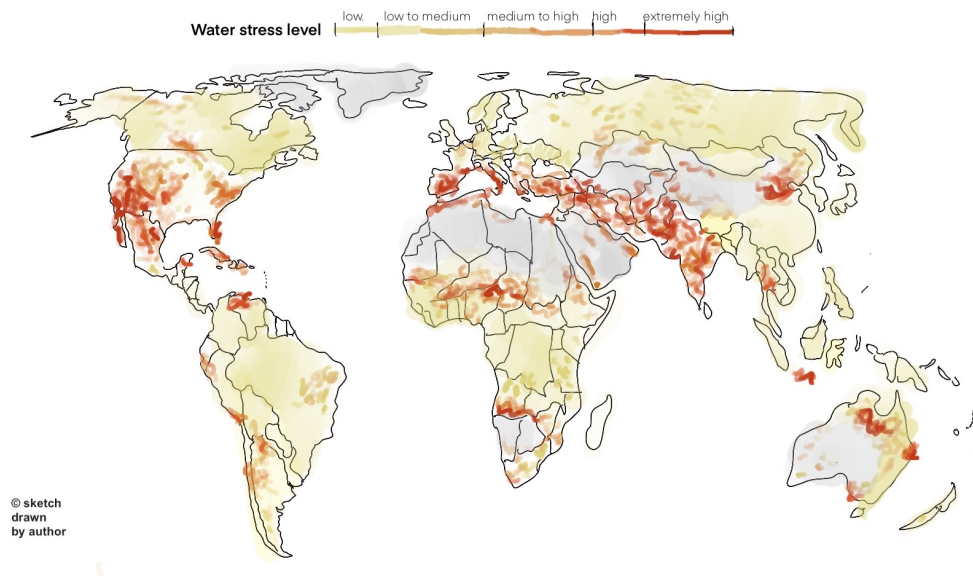


Figure 4.2.: Visualization 2: A sketch drawn by the author

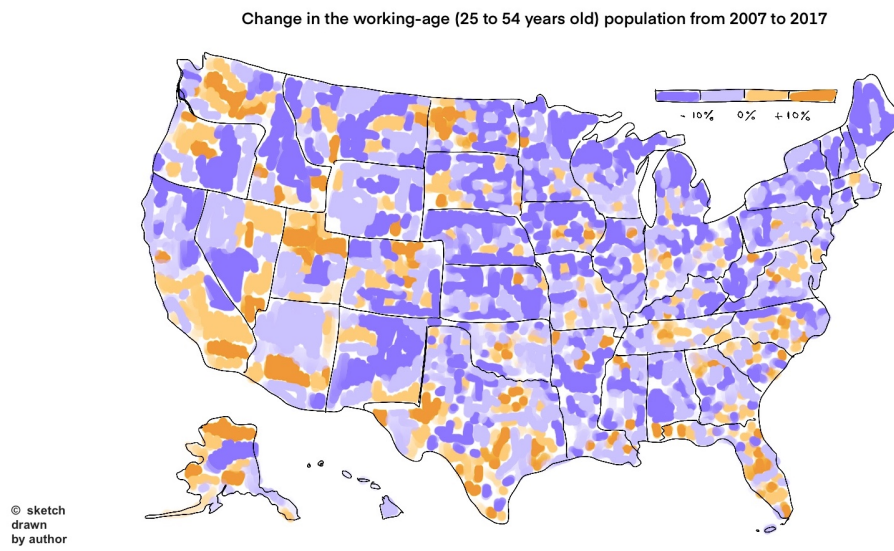


Figure 4.3.: Visualization 3: A sketch drawn by the author

4. Interview Study

4.1.3. Interview and analysis procedure

The study involved 18 participants who took part remotely from their homes, using their personal devices, including 14 individuals on laptops or tablets and four on smartphones. To address our research questions, we employed a think-aloud task followed by probing questions to delve into participants' reasoning processes. This approach allowed us to gain insights into how participants comprehended the visualizations, capturing their sensemaking activities in real time. During the think-aloud task, participants were encouraged to verbalize their thoughts while engaging with the visualizations. We asked follow-up questions to gain deeper insights into their sensemaking activities. The moderator made sure that the participants stayed actively involved or interested by prompting them to provide more detailed explanations of their thoughts when there were periods of silence. After the think-aloud task, we posed additional questions informed by the insights of the first study to explore participants' comprehension processes further. These questions were designed to provide a more comprehensive understanding of how participants interpreted the visualizations and navigated through the sensemaking process. The interviews were conducted in May and June 2023. Participants were asked to select a suitable environment at their remote location with minimal distractions for the interview. Before each interview started, a brief introduction to the study was provided, in addition to the participant information sheet, to clarify the study's objectives and the participants' involvement.

The online interviews were carried out and recorded using the Zoom platform, with each session lasting between 30 and 60 minutes (median = 49:47 minutes). The interview schedule can be found in Table 4.1. The interview process can be outlined as follows:

- **Introduction and consent:** At the beginning of each interview, participants were introduced to the study's purpose and provided informed consent to participate.
- **Demographics:** Participants' demographic information, including educational background, job discipline or study background, current location, and age, was collected.
- **Example visualizations:** During the interview, participants were presented with three visualizations (detailed descriptions in the previous section). They were encouraged to naturally perceive and interpret the maps, explaining their understanding in a think-aloud manner. The initial task description (see 4.1) thus served as an entry point for participants to express their spontaneous thoughts on the visualizations. Subsequent questions were posed after participants signaled that they had no further comments to add to the initial task.
 - *Map literacy:* Analytical questions were posed to assess participants' understanding and interpretation of the displayed maps. This segment aimed to gauge their level of map literacy.
 - *Personal relation:* Participants were asked about their familiarity with and the significance of the topics depicted in the visualizations through open-ended questions.

4.1. Methodology interview study

- *Risk perception:* Participants were prompted to discuss whether they found the maps helpful in understanding the risk depicted on the map.
- *Critical analysis of the map:* Towards the end of the interview, participants were invited to evaluate the maps’ comprehensibility and provide critical insights into their overall design and effectiveness as communication tools.

We transcribed and analyzed the interview data using the qualitative data analysis software Atlas.ti. The audio recordings were transcribed to capture participants’ verbalizations during the interviews. Thematic analysis was applied to the transcripts, leading to the creation of codes that identified recurring themes. We utilized axial coding, following Strauss and Corbin’s [118] approach of axial coding, to group the codes into distinct sensemaking activity themes. A total of 260 codes emerged from the analysis, and a second round of analysis was conducted to ensure the accurate assignment of the codes to their respective themes. The codes were categorized into four sensemaking activity groups: i) visual impression, ii) conceptual meaning, iii) deeper engagement, and iv) affective factors. A list of the codes is depicted in Section A.6.

4. Interview Study

Table 4.1.: Interview Schedule

Introduction and Consent
Demographics
Where do you currently live?
What is your current occupation?
What is your highest completed level of education?
If you don't mind sharing that, how old are you?
Could you tell us some insights of your experience with data visualizations? (Which formats? How long?)
Do you encounter visualizations often? (When and where?)
Are you familiar with thematic maps?
Discussing Visualizations 1 to 3 <i>following sections are iterated per visualization</i>
Task description: Imagine you see this map online or in a newspaper. Please describe in a natural way how you would understand this map and what you would take away from it (message of the graph). In doing so, you may express any thought that crosses your mind. We understand that you may not have much context for the data, and it's okay if not everything is clear. There are no incorrect responses.
First Impression
What type of information seems particularly important on this map?
In-depth Questions
Are you curious about something concerning the map?
What do you think is the purpose of this map?
Personal Relation
Are you familiar with the topic of the map?
Have you ever dealt with this type of map before (Where, when)?
Does the map have any meaning for you and the society you live in?
Risk perception
Do you think the map is helpful to understand the risks of the crisis?
Do you think the crisis is relevant?
Did you learn anything from the map?
Closing

4.2. Results of the interview study

In this section, we present the outcomes derived from users' interactions with crisis maps. The interviews further revealed areas that could be improved to enhance the overall user experience. Our data uncovered four sensemaking activities: visual impression, conceptual meaning, deeper engagement, and affective factors (see figure 4.5). Quotes are listed with a pseudonym to preserve anonymity. As already outlined in Section 4.1.2, we operated with three visualizations, abbreviated as VIS1, VIS2, and VIS3, for better readability throughout this section.

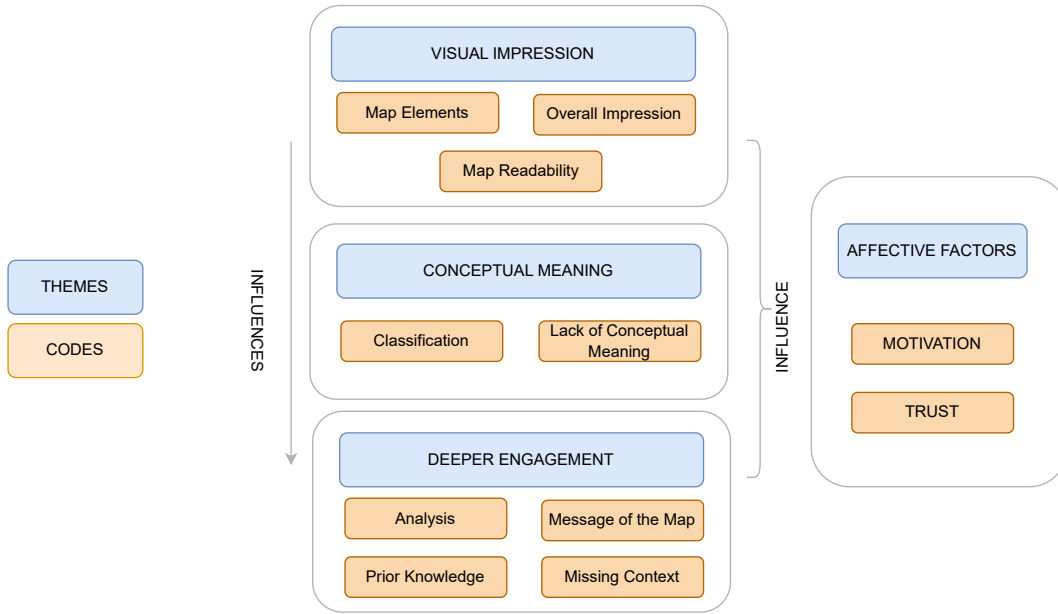


Figure 4.4.: Sensemaking activity clusters and their composition

4.2.1. Quantification of results

Small data visualizations placed alongside words in text can help convey information more effectively than text alone. These small visual elements, known as 'word-scale visualizations,' usually include simple line charts and bar charts that blend into the text seamlessly [121, 122]. To facilitate a quick overview of our results, we also use word-scale visualizations integrated into the continuous text of the result section. This enables a direct comparison of the results from the three visualizations. To maintain an uninterrupted reading flow, this presentation style is exclusively employed for the 'code-level' (orange boxes in Figure 4.5). Our word-scale visualizations utilize a vertical bar graph with three bars, where each bar represents a distinct visualization. An illustrative example below

4. Interview Study

explains the process of interpreting our word-scale visualizations:



Figure 4.5.: Labeled word-scale visualization of the code 'map elements'

Example This figure illustrates the outcomes for VIS1 (depicted in the top bar), VIS2 (in the middle bar), and VIS3 (represented in the bottom bar). The entire horizontal span symbolizes 18 participants. Notably, in VIS1 (highlighted in orange), 17 participants mentioned map elements as first visual impression, while one participant did not reference this particular aspect (indicated by the grey filling). The same interpretive pattern holds for VIS2 and VIS3. Within the continuous text, brackets adjacent specify the precise number of individuals addressing the respective code, presented as [VIS1, VIS2, VIS3]. An example sentence could look like this: Often, participants encoded map elements as their first visual impression  [17,17,15].

4.2.2. Visual Impression

This theme encompasses the perspectives of participants regarding visual elements, such as encoding and assessing visual map elements [17,17,15], outlining the overall first impression of the whole image of the map [6,5,4] and commenting on the map's readability [5,7,0]. The Figure 4.6 provides an overview of the whole theme.

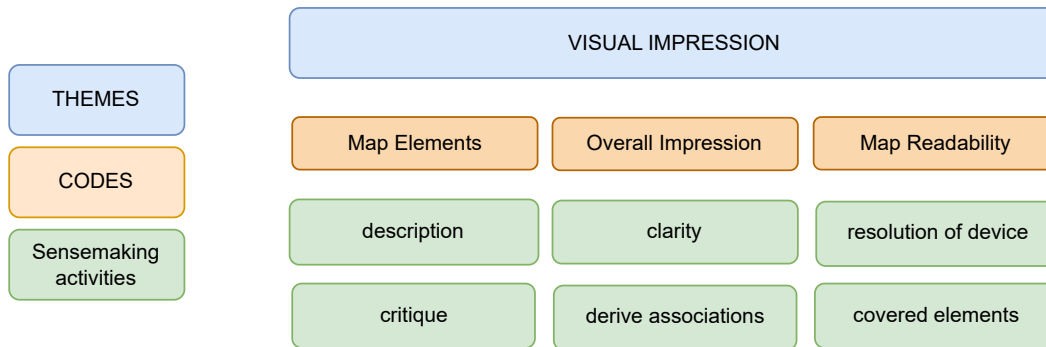


Figure 4.6.: Sensemaking activities for the first theme 'visual impression'

4.2.2.1. Map elements

Participants often described map elements as their first impression of the visualization. Some also provided criticism of the elements used.

“So, there is a map of the U.S. with COVID-19 cases in the government district. And they are shown by these red circles.” – P16-VIS1

Description In almost all interviews, color, title, and map excerpts were the first elements to be mentioned for all three visualizations. Next to those visual variables, participants also encoded other elements on the map. Naturally, the outlined elements differed concerning the type of map. For the first visualization, symbols were read out 13 times. For the second map, eleven participants outlined the legend, and twelve participants outlined no-data fields as visual variables. Whereas for the third map, map sectioning (mentioned eleven times) and the legend (mentioned twelve times) were prominent elements to be identified as first impressions.

Critique Some Participants also criticized visual concepts positively. They indicated that the contrast of presented colors is fitting because results are separable on the first

4. Interview Study

glance. Or criticized the contrast of colors because the background of the map is not clearly distinguishable from the background.

4.2.2.2. Overall impression

When looking at the graph for the first time some participants also mentioned their overall impression of the whole visualization. They comment on the clarity of the map and sometimes also outline any upcoming associations.

Clarity Some participants perceived the visualizations as messy and complicated. Whereas others found the map clearly arranged. Again, participants mentioned that the color caught their attention right away, solving as an eye catcher.

“First of all, I feel like it’s a lot, and it looks so messy at first with all the red circles.” – P10-VIS1

Derive associations In the first visualization three participants mentioned that they immediately got a feeling of ‘warning’ as they have seen the map. For the second visualization two participants outlined ‘climate change’ as first association during the first impression.

“So at the very beginning, when you opened the graphic, climate change popped into my head.” – P9-VIS2

For both implications the chosen color concept was outlined to be the primary cause for this association. One Participant outlined that the recency and urgency of the topic could also explain this connection.

4.2.2.3. Map readability

Most of the participants were able to read the map without complications. However, sometimes participants outlined that map elements are hard to recognize because of their blurriness, indicating **resolution** issues or the usage of small devices. In some cases important **map elements were covered** by zoom elements leading to issues for further understandings. For example in VIS2 three participants confused ‘missing data’ fields (colored grey) with the lowest expression of the measured variable, because the explaining key was covered.

4.2.3. Understanding conceptual meaning

Once participants visually inspected the map, they tried to understand the map elements conceptually [18,18,18]. This cognitive operation involves identifying the meaning behind used map elements. For instance, participants tried to derive the underlying meaning of 'proportional-growing circles' on VIS1. They derive that a growing circle indicates a higher number of COVID-19 cases. Participants also mentioned a lack of understanding of depicted map elements [15,18,17].

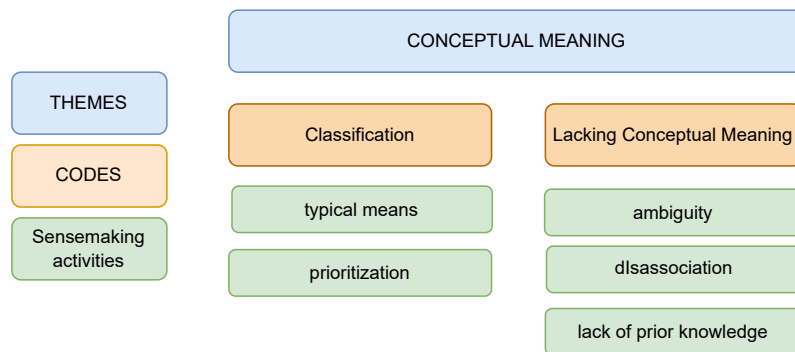


Figure 4.7.: sensemaking activities for the second theme 'conceptual meaning'

4.2.3.1. Classification of map elements

Participants classified map elements according to their typical means and their importance on the map (prioritization) while relating map elements to their meaning.

Typical means Participants perceive elements as typical means, indicating that they are easy to grasp because of their familiarity. This familiarity is often explained by map features being widely seen in different types of media or in school and work settings.

"I think there are super many infographics with the same principle. So that the size of icons represent how much is happening in which locations, I think this is relatively common." - P18-VIS1

"I have seen similar maps in the ZEIT online app. [...] but I don't think: Hey, what is this supposed to mean? So this all looks familiar to me already." - P10-VIS1

For VIS1, four participants considered the concept of 'growing circles' as a typical means. Additionally, one participant noted that the background color 'grey' for VIS1 felt familiar and thus considered it a suitable choice.

4. Interview Study

Prioritization Three participants also rated map elements based on their importance of the maps message. In VIS1 two participants recognized the intensity of color as more significant than symbols (circles) represented on the map.

“Now I notice that I pay less attention to the size of the circles than to the intensity of the color. So even though I see very, very large circles, I perceive many small red circles that create a very dark red color, somehow, stronger.” – P2-VIS1

Another participant emphasized that the case numbers outlined for each state in VIS1 are the key information of the whole map.

4.2.3.2. Lacking conceptual meaning

Some map elements resulted in confusion because of their ambiguous and dissociative nature as well as participants’ lack of prior knowledge in order to relate map elements to their meaning.

“No, actually. Something is missing there. There is something missing for me to have a logical connection. There’s a gap in my mind. And no matter how much it’s whirring right now, I can’t figure out what really... What does the title really mean?” – P7-VIS3

Ambiguity Ambiguity occurs in the context of maps when individuals perceive that the concepts or elements within the map have more than one possible meaning or when their meanings are unclear. Certain symbols, labels, or representations might be open to different interpretations, leading to confusion among users. Here, we highlight the most prominent concepts:

In the first visualization, 11 participants encountered several sources of ambiguity, including overlapping circle symbols (eight participants), the use of absolute values (five participants), and insufficient text labels (four participants). The overlapping circle symbols and the resulting intensified red color raised confusion, as participants were unsure whether these symbols had any specific meaning or were merely visual artifacts. The use of absolute values instead of proportional values caused confusion as participants had difficulty interpreting the magnitude of the crisis. Moreover, insufficient text labels on the map created difficulties for some participants:

“Underneath, I can’t precisely determine whether that represents the population count, for example, in Nevada, 72,300 plus, or if those are the cases. It’s not entirely clear to me, but probably they are the cases. That’s what I would think for now.” – P13-VIS1

In the second visualization (VIS2), all 18 participants encountered various sources of ambiguity, particularly labeled ‘missing data fields’ (15 participants). The grey-colored fields (= missing data) raised the question of why the data is missing in these regions.

4.2. Results of the interview study

Also, the lacking definition of the measured variable 'water stress' led to confusion (eight participants):

"Okay, the first question that comes to my mind when looking at the map is, what does water stress mean in the context of this map? Is it water stress of drinking water, water stress for agriculture, water stress in general for the economy, or something else? Does water stress consider highly seasonal or time-limited dry periods? These are definitely pieces of information that cannot be inferred from the map at all." – P16-VIS2

In the third visualization, 14 participants faced ambiguity regarding the definition of the measured variable and the color key (nine participants). This map proved to be particularly challenging for participants, as the variable's definition was not clearly specified, leaving them in a state of confusion.

"I find the legend to be confusing. [...] Because it doesn't clearly explain what the '+ 10' and '- 10' percent represent. I assume it has something to do with the working-age population between 25 and 54, whether it has gotten older or younger. But I can't say for sure if it means there are more or fewer people in that age group." – P14-VIS3

Furthermore, the color key was perceived as unsettling, as it failed to facilitate understanding the definition of the variable. Instead, the presented percentage values of the color key contributed to even more perplexity.

Disassociation Numerous participants raised concerns about the dissociative nature of certain map elements. This was particularly evident for color concepts used in VIS2 (seven participants) and VIS3 (three participants).

"Without having read above what the colors mean, I thought it had something to do with heat because red and yellow-red are colors associated with heat. And yes, now I read that it's about water stress. So my assumption wasn't correct at all." – P13-VIS2

Participants faced challenges due to the absence of clear associations with the selected color concepts. They criticized the lack of guidance provided by the color choices, making it harder to interpret the graphics.

Prior knowledge Lastly, Participants' lack of prior knowledge in combination with used map elements or the lack of them resulted in confusion.

"I am currently checking to see if we are visible somewhere on the map, but I don't think so. Oh, this is not Austria..." – P8-VIS1

The participant is expressing their current activity of checking to see if a particular location is visible on a map. However, they realize that the map does not represent Austria, as initially thought. The confusion arose because of the absence of labels on the map, coupled with the participant's limited prior knowledge about the geographical area.

4. Interview Study

4.2.3.3. Strategies to deal with lacking concepts

The participants adopted different strategies to counter their confusion due to the lack of conceptual meaning regarding map elements. The following section provides a concise summary of their approaches.

- **Make assumptions about map elements:** When the meaning of a concept was not entirely clear, participants tended to make assumptions and attempted to reason further by relying on their own knowledge.

“Actually, I don’t know what’s behind the grey fields. Either everything is perfect, or it’s going so well that they don’t need any water. Or, that’s all I could imagine, well, I can only speculate.” – P7-VIS2

“Where does the information come from? When was the map created? Or what time period does the map depict? I can only assume that the map is current because it might be related to a more recent topic.” – P2-VIS2

Prominent examples of confusing map elements are labeled ‘missing data fields’ and ‘unclear meaning of the variable’ and prompted participants to engage in assumptive thinking.

- **Argue about the possibility of misinterpretation:** Participants expressed concerns that poorly defined or understood map elements could result in misinterpretations or incomplete conclusions.

“That means that the absence of so much data can lead to many misinterpretations, in my opinion.” – P18-VIS2

“Or rather, I believe the map can also be easily misunderstood if, for example, the title is misinterpreted or something like that.” – P2-VIS1

Specifically, issues related to the ‘unclear meaning of the measured variable,’ ‘dissociative color concepts,’ and the ‘use of absolute values’ instead of proportional ones were discussed as contributing factors to these challenges.

- **Lacking concepts harm understanding:** Participants criticized that lacking concepts harmed their understanding. Reasons are poorly defined variables, unsuitable color choices, and ambiguous symbols.

“So, I don’t think I understand the map at all. Firstly, I don’t know which country it is. And then, I don’t know what ‘change’ is supposed to mean.” – P17-VIS3

Moreover, the absence of orientation aids, such as city names and country labels, was negatively perceived by two participants.

- **“I am not an expert!”:** Certain participants experienced a notable sense of uncertainty and self-doubt in their map-reading abilities, primarily driven by the perplexing nature of the concepts presented.

4.2. Results of the interview study

“Well, there’s quite a lot of purple in the middle, so minus ten percent. But as I said, I’m not a map expert, so I can’t filter out what’s going on. So what does minus ten percent actually means. Right.” – P8-VIS3

“Yes, well, I find it very confusingly presented because of what I just said. It’s not clear to me if ‘County’ is the same as ‘State’. Probably not, maybe ‘County’ refers to each small village. Oh, I don’t know. This should be clear to me, definitely. Maybe I’m just uneducated about this.” – P17-VIS1

The foremost contributing factor to this statement was the lack of clarity of the measured variable.

- **Suggest a different design:** The presence of conceptual gaps within the maps requires participants to seek additional information. In particular, participants expressed concerns about the color key, emphasizing the necessity for a more detailed description. As a consequence, some participants deliberated on potential color design modifications that could render the graphics more intelligible.

“Perhaps it would have been more helpful if each category had been assigned a distinct color, with ‘low’ represented by one color, ‘medium’ by another, and ‘high’ by a third color.” – P18-VIS2

Participants proposed the adoption of more appropriate colors based on prior experiences. They advocate for colors which correspond more effectively to the intended themes or evoke specific positive or negative associations.

4. Interview Study

4.2.4. Deeper engagement

Participants attempted to extract deeper meaning from the graphic by analyzing it [16,17,13], identifying the purpose of the graphic [16,17,9], leveraging their own knowledge [13,17,14], and talking about missing contexts [12,12,7].

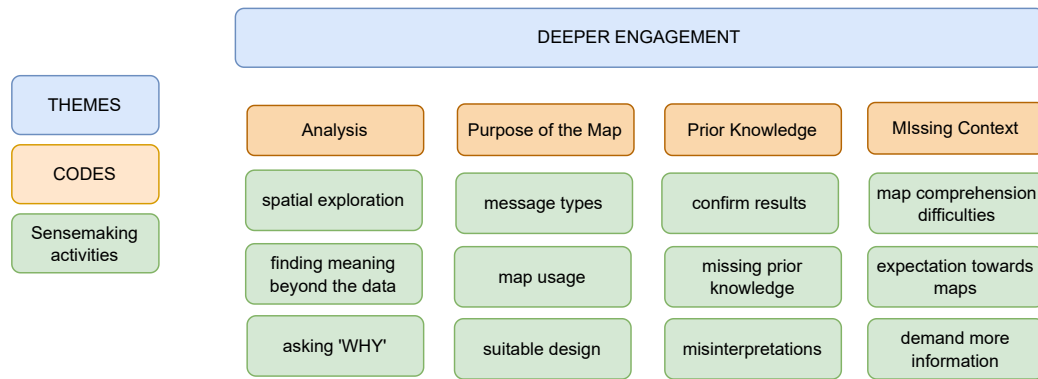


Figure 4.8.: Overview of sensemaking activities for the third theme 'deeper engagement'

4.2.4.1. Analysis

After visually processing a graphic and attributing meaning to its map elements, participants delve into analysis. They explore the spatial distribution of data, seek meaning beyond the data, and wonder about possible causes of the crisis depicted on the map.

During their engagement with the map, participants performed little analysis. Many of them **explored the map spatially**.

"I look at regions where I can try to estimate the extent of water stress." – P16-VIS 2

They occasionally focused on regions with which they were familiar with. Moreover, participants actively posed questions and sought answers to deepen their understanding. Additionally, they ascribed **meanings beyond the presented data**. They outline associations and formulate empathetic reflections concerning crisis-affected areas. Many participants identified trends and derived conclusions about possible causes of the crisis (**Asking 'why'**).

4.2.4.2. Purpose of the map

Participants engage with the purpose of the map by contemplating the types of messages, the intended use of the maps, and whether the map's design aligns with the message conveyed in the graphic.

4.2. Results of the interview study

Message types The participants understood different messages from the map. The most common messages include: Having a geographical overview of the crisis, creating awareness of the crisis, and seeing the map as a warning. Three participants emphasized that using signal colors helped them to interpret the map as a sign of 'warning.'

"So the color selection alone is just very strong, yes, just a very strong signal [...] you really look at it a bit shocked and then see the striking outbreaks of corona in some regions. So to describe the seriousness of the situation, it was definitely a good representation" – P15-VIS1

Interestingly, two participants expressed confusion regarding their initial statement that they had perceived the map as a warning. They distanced themselves from their previous assertion and questioned whether the map really conveyed a warning message:

"Intuitively, one would definitely associate it with risk simply because of the larger size and, especially, the red color of the circles. That naturally evokes a sense of risk, but in reality, the map does not represent that." – P16-VIS2

When participants read out the message that the map was intended to create awareness of the crises, some of them also expressed a sense of personal responsibility.

"We have a water shortage that already exists and is getting worse, so we should simply be mindful not to waste water." – P1-VIS2

"Maybe there is another message directed towards the average statistical reader like me, that we should perhaps waste less water." – P14-VIS2

This prompted them to rethink their own behavior and consider preventative measures in response to the crisis.

Map usage Furthermore, some participants highlighted the significance of the map serving as a decision support tool.

"I mean, in the end, even government officials might look at such graphics and draw their conclusions from them." – P14-VIS1

They recognized its potential to provide valuable insights for decision-making processes.

Suitable design While analyzing the purpose of the map, participants also evaluated the map design:

"Indeed, I believe that as a first step or an overview, the map is well-designed as it is." – P12-VIS2

"However, otherwise, I believe that for an overview, it is completely sufficient and provides all the information I would need." – P18-VIS1

Some participants expressed positive opinions about the map's design, indicating that, in their view, the map effectively achieved its intended goal.

4. Interview Study

4.2.4.3. Prior knowledge

With the aid of their prior knowledge, participants could verify the results on the map. However, some participants lacked previous knowledge to interpret the graphic more profoundly. Participants argued that this could lead to misinterpretations.

Confirm results Participants actively engaged their prior knowledge to contextualize the presented results, thereby establishing a personal connection with the data.

"In Austria, for example, we now have to increasingly consider how we manage groundwater. It is becoming a more prominent topic, and certain areas may need to be reevaluated in terms of how we handle water resources. When I see places like Neusiedl or others where the water level is drastically dropping, it should definitely make us reflect on the situation." – P3-VIS2

When the observed results align with their existing knowledge, some participants openly confirmed their expectations of the results:

"And now I see that, for example, India is heavily affected by it. But that also makes sense because it's very hot there." – P7-VIS2

However, there are instances where participants come across information on the map that contradicted their prior knowledge, sometimes also leading to expressions of surprise:

"I mean, I'm partly a bit surprised that there are certain areas that are now in the lower range. I didn't imagine it that way, but yes." – P4-VIS2

Missing prior knowledge Participants occasionally acknowledged their limited prior knowledge concerning the topic the map depicts.

"I am currently trying to reflect on why I struggled to understand it at first. I believe it's primarily because this isn't a topic I've ever really delved into before." – P4-VIS3

Two participants mentioned that their lack of prior knowledge prevented them from deriving any further conclusions from the map. Furthermore, participants also argue that without adequate prior knowledge, understanding the map becomes challenging, and there is a risk of **misinterpreting** the information presented.

4.2.4.4. Missing context

Participants frequently mentioned the absence of context of the provided map, expressing **difficulty in understanding** it as a result. As a result, they have expectations for the map to provide more clarity. Adding additional information, especially in a textual format, is suggested to enhance the comprehensibility of the map.

Participants frequently expressed their dissatisfaction with the maps, highlighting a perceived lack of contextual information.

4.2. Results of the interview study

"So, if it's not completely out of context, I would say that having some text or information beforehand, or telling people what it's about, would be helpful. But if you just get this map without any context, like right now, I find it a bit difficult to understand." – P6-VIS3

Sometimes participants described the maps as non-speaking entities, as they fail to provide sufficient context:

"I also find it difficult to think about the message of the map when you don't know from when it is and also don't know how this water scarcity occurred and in what context the map is used, like what it's being used for. I'm not sure, there's just a lack of information." – P10-VIS2

They emphasize that the absence of such information complicates the comprehension process and forces them to make assumptions or rely on their own prior knowledge.

"Also, yeah, I can't really make sense of the map except to guess, somehow."
– P2-VIS3

Consequently, some participants articulate their **expectations** regarding maps in general. They believed that maps should be easily and quickly understandable, providing a sufficient level of context that eliminates the need for making assumptions:

"And when I look at a graphic, I don't want to speculate or improvise. That's not the purpose. I just want to quickly glance at the facts. Ah, okay, got it, and move on. In this case, I would have to stare at it forever and still not understand. It's just misleading. Absolutely. Next, please." – P7-VIS3

To overcome this limitation, participants expressed a strong desire for **supplementary information**:

"Certainly. So, I could almost say that it might be different if it were explained in a text. Like, why or how the developments happened, I don't know. I think I would need something, a short text to get familiar with it, so that I really understand it." – P3-VIS3

They proposed to add more text where impacts and causes are outlined in detail and add additional variables, which would give the map more causality.

4. Interview Study

4.2.5. Affective factors

Participants mentioned motivational [14,11,12] and trust factors [10,9,5] while engaging with the map, highlighting aspects that either positively or negatively influence their personal connections to the information presented.

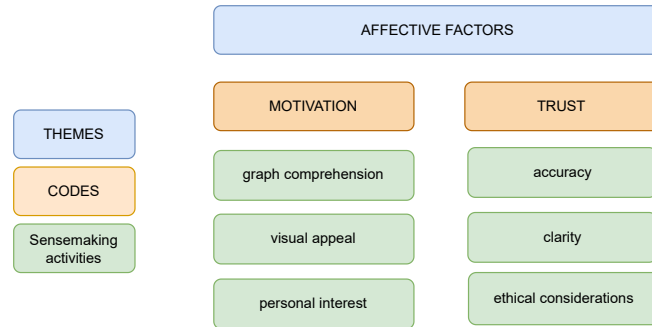


Figure 4.9.: Overview of sensemaking activities for the fourth theme 'affective factors'

4.2.5.1. Motivation

The motivation of participants to engage with a map can be influenced by various factors, including map comprehension, the personal interest towards the topic, and the visual appeal of the map.

Graph comprehension Participants expressed a lack of motivation to engage with maps that are complex or difficult to comprehend.

"I would immediately move on. I mean, I would read it, then probably briefly wonder if I missed something or if there are more details. But I've tried that now, and I definitely do not understand anything. So, I don't think I would spend any more time on it." – P17-VIS3

Visual appeal We found that the visual appeal of the map can positively or negatively impact motivation:

"I find purple and orange relatively pleasant together. Therefore, it is also visually pleasing, one enjoys looking at the map." - P18-VIS3

Pleasant colors and a simple layout enhance motivation to interact with the map, while a chaotic or visually unappealing map can decrease motivation.

Personal interest Personal relevance plays a significant role in motivating participants to engage further with the map. Some participants identified the topic itself as interesting, regardless of the specific country shown on the map. Others felt motivated due to the direct impact of the crisis on their lives. However, some participants may lack motivation if, for example, their home country is not represented or if the topic is not of interest:

"I believe the population development of the USA is not something that personally interests me, so I wouldn't engage with it." – P18-VIS3

The recency of the topic can also influence motivation, with participants feeling motivated to understand current and relevant issues. On the other hand, some participants may feel demotivated by the past nature of the crisis or perceive it as overcommunicated. In VIS2, two Participants stated that the topic of COVID-19 is overcommunicated, and their motivation to engage with the topic is rather low:

"Due to the fact that so many maps are circulating in the German media, whether they are circles, bars, or colored districts, they are self-explanatory, and they don't particularly pique my curiosity." – P12-VIS1

4.2.5.2. Trust

Participants' trust is influenced by several factors, including the accuracy and reliability of the data, clarity of information, and ethical considerations. Some participants emphasized the importance of checking the source to trust the map. Positive influences on trust include a trustful source. Participants also perceived maps as trustworthy if missing data fields were labeled, indicating honest map creators:

"While I must also say, perhaps the fact that certain information or data is missing could be an indication that the data depicted on the map are accurate. It is possible that someone creating a map would not use unreliable data or invent data and insert them into the map." – P2-VIS2

However, some participants expressed a need for more detailed information (**accuracy**) about the data, how it was calculated, when it was collected, and when the map was published. The lack of such details negatively impacted the trust of participants.

"Yes, my trust diminishes because something is missing. Actually, the lack of information raises suspicion because I would like to seek a second or third opinion or simply find out more by researching myself." – P7-VIS2

Secondly, the **clarity** of the map and its components also plays a role in trust. Participants state that when data or map elements are presented in greater detail, the map appears more trustworthy to them:

"I don't know, I think I would trust the map more if it was more differentiated, showing precisely what each [circle] size represents." – P9-VIS1

4. Interview Study

Lastly, **ethical considerations** influence trust as well. Participants question the omission of data for countries facing structural problems:

"I initially thought that it might be due to data not being collected because the countries were considered unimportant by the source. It could indicate a structural problem, and the data might even be unreliable." – P2-VIS2

They perceive it as a lack of interest in the data source due to the countries' economic status. This led to a decline in trust as participants viewed the omission as a bias that favors more developed countries.

5. Discussion and Conclusion

In both of our studies, we focused on how Digital Natives comprehend map visualizations related to crisis issues. To achieve this, we conducted an analysis of discussion comments submitted to the New York Times Series "What's Going on in this Graph?"¹, specifically on crisis-related maps. We further explored our research question in semi-structured interviews. The insights and findings obtained from this comment analysis served as a valuable foundation for the development of our interview schedule. These interviews provided us with an opportunity to delve deeper into our research question and gain a more nuanced understanding of how Digital Natives interact with and interpret crisis-related map visualizations. By combining both the comment analysis and the results from the interviews, we aimed to gain valuable insights into the cognitive processes and challenges faced by Digital Natives when engaging with map visualizations in the context of crisis issues. Before we discuss those in detail, we want to discuss our methods and their influence on our results.

5.1. Discussion of methods

Our study utilized two distinct methods to obtain results, and it is essential to delve into their impact on the outlined findings. Notably, factors such as anonymity and social desirability [123, 124, 125, 126, 127, 128], real-time exploration [47, 129, 130, 131, 132], and the role of the researcher [55, 106, 124, 133, 134, 135, 136, 137] have shown to be instrumental in influencing the outcomes of these methods. By examining these factors in greater detail, we better understand the significant differences they introduce to the employed methods and their implications for our study's results.

5.1.1. Anonymity vs. social desirability

One benefit of analyzing online content is that it was not created in an artificial study context. Studies have shown that when participants feel less observed, more honest results can be obtained [123, 124]. In our comment study, we observed that some participants expressed polarizing views by sharing unsolicited political beliefs or intimate details from their personal lives. However, comments in the series can also be semi-anonymous, as often entire classes participate in the commenting process. Class teachers frequently monitor and respond to the published comments of their students, serving as a form of control. This method offers the benefit of enhancing the quality of the results by reducing the occurrence of irrelevant comments from participants. However, it may also reduce

¹<https://www.nytimes.com/column/whats-going-on-in-this-graph>

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the level of honesty with which participants respond, as they may feel inhibited due to the presence of authority figures and the potential for social evaluation. In interview studies, participants interact directly with the interviewer, which can create a personal connection. Their responses are tied directly to their identities, which could lead to a higher sense of accountability for their responses. Participants may prioritize their self-perception, wanting to avoid negative judgments from others. They might want to answer 'the right thing' even when there is no such thing in the eyes of the researcher [125]. We also found that participants sometimes felt the need to reflect on their statements, provide justifications, or clarify their understanding, particularly when they struggled to comprehend the visualizations. They were also searching for approval in their statements. As already outlined in other studies [138, 139], we also found that tactics such as humor, self-disclosure and expressing interest in participant's responses helped to overcome social desirability issues. Along with other studies [126, 127, 128], we also recognized the importance of a non-judgmental and supportive environment where participants feel at ease to express their thoughts and experiences openly and honestly. Such an environment can encourage participants to provide valuable insights and contribute to a greater level of authenticity.

5.1.2. Real-time exploration

In the research field of sensemaking in Human-Computer Interaction (HCI), it is crucial to explore and understand how people make sense of a concept in real time. In essence, the 'real-time' aspect of sensemaking research emphasizes capturing and analyzing the immediate and evolving nature of how individuals comprehend information during their interactions. Qualitative methods like semi-structured interviews provide an opportunity for real-time exploration of participants' comprehension [47, 129, 130]. Our research observed and analyzed the naturally engaged thought processes of participants while comprehending visualizations. We know that our thoughts happen really quickly, much faster than we can actually talk. So, to understand what people think when they see a visualization, we asked them to speak out loud about their thoughts right at the beginning. This way, we could catch their immediate reactions and understand how their minds work the moment they see the map. Therefore, a think-aloud question at the outset could encourage participants to express their thoughts in the moment of encountering a visualization, allowing to capture their immediate reactions (and cognitive processes) as they unfold. We noticed that this approach had several advantages compared to our comment-based study. Participants shared their spontaneous impressions and gave more detailed responses. We gained a better understanding of how they naturally made sense of the visualizations without specific prompting. However, our findings also revealed that comments frequently did not include details about participants' visual impressions. This could be attributed to the structured nature of the comments because the predefined question structure did not prompt participants to provide such information. Future research could investigate whether open-ended questions within the comment-based format could yield similar exploratory results compared to interview studies. Many studies in the sensemaking field within HCI, which rely on user comments, also explain

that comments alone may not be sufficient to gain a comprehensive understanding of the sensemaking process [131,132]. Thus, using comments in combination with other qualitative methods such as interviews, observations, or questionnaires likely paints a broader picture and captures various aspects of sensemaking processes.

5.1.3. Role of the researcher

Researcher guidance is important in interviews related to sensemaking. It helps to ensure that participants are provided with clear instructions, prompts, and frameworks to guide their thought processes and reflections [133,134]. We also found, that participants actively sought guidance and validation from the interviewer during their sensemaking process. This parallels other studies that emphasize the collaborative nature of sensemaking in which the interviewer reportedly plays an active role in helping participants to explore and understand their thoughts further [55,133,134]. Accordingly, we underline the importance of an active and engaged interviewer who can provide support, prompts, and additional insights to enhance the sensemaking experience for participants. However, it is important to be cautious about potential biases that may arise from researcher guidance, which we have taken into consideration in our study [106,135,136]. In comment studies, participants have the freedom to express their thoughts and interpretations without direct influence from the researcher. This lack of influence from the researcher allows for a more open and uninhibited expression of participants' perspectives. In our study, we observed that this approach resulted in less in-depth analysis compared to other methods. However, it has the advantage of minimizing potential biases introduced by the researcher's influence. Previous studies have suggested that comment-based approaches may result in a broader spectrum of perspectives and a more diverse set of responses [124,137]. This is due to the participants' ability to freely share their thoughts and interpretations, unrestricted by the researcher's influence. In our study, we noticed that the responses from participants were relatively homogeneous. We argue that this may be attributed to the simplicity of the question structure that guided the comments but would need to be explored further in future work.

5.1.4. Sample bias

It is important to acknowledge that the samples of both studies are biased and are not representative of all Digital Natives. In the comment study, individuals either choose to engage voluntarily in the series or are prompted to do so as part of their school projects. It is important to acknowledge that a substantial part of the sample is likely to be from the United States. It is crucial to recognize that these factors can influence the content and tone of comments in ways that are beyond our control.

Similarly, for the interview study, there is a bias in the results as most participants were interviewed from German-speaking regions.

5.2. Discussion of results

In the following section, we present the key findings from both the comment and interview studies while taking into account relevant existing research and its potential implications. It is important to note that the comment study and the interview study are based on each other and are not meant to be directly comparable, as different participants were targeted. To facilitate clarity and readability, we will refer to the comment study as 'Study 1' and the interview study as 'Study 2'.

5.2.1. The right degree of personal connection

During the first study, participants actively sought to establish personal connections with the data. They described their own experiences with the crisis, assessed risk factors in geographical areas linked to their residences or personal connections, and expressed their individual opinions. This has also been observed in the works of Hogan et al. [135] and Nowak et al. [136]. Both studies report that participants proactively search for personal associations on the map to verify information and reinforce their understanding of the visualization. Additionally, they found that participants often derive deeper interpretations beyond the visualization based on these personal connections. On the other hand, in our sample, we observed that when participants strongly identify personally with the topic, these deeper interpretations can sometimes divert their attention from the intended message of the map. Consequently, their emphasis on personal connections might hinder them from fully grasping the map's message. In Study 2, participants also tried to relate to the information on the maps by recognizing places they were familiar with and verifying the displayed results. However, the majority of the maps in the study either featured excerpts unrelated to their home country or covered topics they were familiar with but not experts in. These circumstances, especially the first point regarding unrelated geo-locations, resulted in a less personal connection to the visualization. Sometimes, this even hindered their engagement and interest in the map because the content wasn't directly relevant to their experiences or expertise, especially when the maps used complex map elements whose meaning couldn't be easily decoded at first glance. Insights from our two studies show that the sensemaking of crisis maps depends on understanding how people personally connect with the content. In the first study, participants' excitement and strong personal interest in the crisis topic sometimes impeded their understanding of the map. This suggests that being too emotionally connected, even though it shows genuine interest, can make interpretation more difficult for participants. On the other hand, the second study reveals that participants lost interest when the map didn't relate to their experiences or interests. Therefore, map designers need to find the right balance, considering the emotional resonance and personal connections of the audience. They must navigate the fine line between capturing the audience's interest without overwhelming them or creating a sense of detachment. These results are consistent with previous research, which emphasizes that maps are not always prone to a 'one-size fits all' approach [85]. This approach is seen as essential for creating maps that communicate information to a wide range of users with different levels of map

literacy and varying contextual knowledge [85,140].

5.2.2. Sensemaking is a process

In both studies, we identified a series of interrelated sensemaking activities. In Study 2, we observed four groups of sensemaking activities: i) visual impression, ii) conceptual meaning, iii) deeper engagement, and iv) affective factors. The first three groups generally occurred in the mentioned order, with each group building upon the previous one to further the thought processes. This progression suggests that participants go through a gradual process of sensemaking, with each group building upon the preceding one to augment participants' cognitive processes. Our findings about sensemaking being a multi-stage process align with results from other studies [141,142,143]. Researchers have identified three types of thought processes often referred to as the three-level graph comprehension theory: encoding visual data, linking visual attributes to concepts, and connecting concepts to prior knowledge [27,58,60,144]. This theory also has been tested and validated for unknown visualizations [15] and interactive map visualizations [60]. Furthermore, other studies focusing on data reuse [55] and data exploration tasks [142,143] identified similar steps in the sensemaking process. However, these earlier studies seldom addressed affective factors, presumably because they did not examine visualizations depicting a crisis context. In both of our studies, participants expressed affective responses to the maps. Depending on the level of personal identification with the crisis, this affective connection influenced their sensemaking processes (see 5.2.1). Consequently, both of our studies revealed a notable affective link between individuals and the presented maps. We, therefore, outline another sensemaking-step: 'personal connection' in Study 1 and 'affective factors' in Study 2.

It is widely argued in literature that crisis visualizations have the potential to evoke affective responses [106,135,136,145,146,147]. For instance, Zhang et al. [2] have presented several COVID-19 map visualizations and explored the impact on cognition, trust, motivation, and other pertinent factors. Along with other research [148,149,150,151], they emphasize the emotional impact of visualizations. Along with those studies, we emphasize future research to delve into the dimensions of the felt and lived experience of crisis visualizations in news media. Such investigations can foster a deeper understanding of the emotional repercussions and impact of crisis maps.

5.2.3. Color matters

In 'Visualization Analysis and Design' by Tamara Munzner [69], the exploration of the question 'What is Color?' and its profound significance in visualizations is approached systematically [69, p.218]. The discussion delves into various aspects of utilizing color and other nonspatial elements in the design of visual encodings. When referring to 'color,' the discourse essentially considers three aspects: brightness (luminance), color type (hue), and color intensity (saturation). The findings of our second study also underscore the pivotal role of different color hues, especially during the initial visual impression of a map on viewers. As identified in previous research [60,135], participants often mentioned

5. Discussion and Conclusion

color as one of the first map elements. Color hues especially play a significant role in cartography [2, 46, 56, 106]. Color hues were also a focal point in both of our studies. In Study 1, participants routinely utilized color types referencing regions affected by crises. For instance, they articulated geographical zones by employing descriptors such as 'the red zones, the blue zones,' and so forth. Interviewees of Study 2 also discussed the significance of different color types for interpreting crisis maps. Notably, some participants expressed criticism regarding the inability to associate color concepts with specific positive or negative connotations. Such challenges hindered their perception of the severity and scope of the crisis depicted in the visualizations. These findings resonate with a study conducted by Fang et al. [46], which employed eye-metrics to explore the influence of different color concepts (color hues and color intensity) on crisis maps. Fang et al. found that a color scheme featuring warm tones, particularly tending towards red, possessed a distinct advantage in terms of visual prominence. Consequently, users required less time to assimilate crucial information during initial processing compared to other color variations. Moreover, other studies support the notion that red, being the most commonly employed warning color, enjoys a high level of familiarity in the mental representation of working memory [152, 153]. However, our findings also revealed that red might not always represent an optimal color choice to display crisis issues. An example of Study 2 showed that in the second visualization, the variable water stress was visualized using the red color. However, because many participants associate water with the color blue, they were initially confused, thinking that the visualization represented heat or drought instead. This highlights a potential mismatch between the conventional associations of colors and the specific variables they are intended to represent in certain contexts. Therefore, the choice of red in crisis maps might lead to confusion or misinterpretation, and alternative color options may be more suitable for effectively communicating the intended information. This observation aligns with similar implications discussed by Szafrin et al. [154]. In their research, they underline the importance of understanding color perceptions in the context of visualizations (and their depicting topic). Future work will need to consider which color choices are the most suitable in order to use color concepts in crisis maps more effectively.

5.2.4. A map needs context

Maps present geographical information and illustrate spatial patterns. Numerous studies have demonstrated that information conveyed through graphics is easier to comprehend compared to textual content [63, 155, 156]. However, both of our studies also revealed that map visualization can have limitations when it comes to conveying detailed information about spatial regions or relationships. For example, some participants in Study 1 needed more information to realize that a map only represented future predictions or probable scenarios. In Study 2, more context would have helped to encode ambiguous or dissociative perceived map elements. Therefore, participants in both studies faced difficulties in understanding the maps because of missing contexts. As a result, they expressed the need to provide additional, potentially textual, information. Participants of Study 2 also saw the possibility that the map could appear overloaded if additional information

were included. Other seminal works support the idea that the balance of text and visual artifacts is needed [61, 62, 68]. Furthermore, participants in Study 2 argued that the map should, therefore, be complemented with other forms of representation. This is in line with research findings from Hullman et al. [86], who suggest that using various forms of representation, such as text, diagrams, or interactive visualizations, can lead to better comprehensibility and information absorption. A recent study by Koesten et al. [157] outlines the pivotal role of textual elements in visualizations to engage with readers. They outline the importance of embedding context in visualization, highlighting the fact that charts can easily be taken out of context in public discourse, as seen in recent crisis events [158].

5.2.5. Missing data and trust

Missing data in visualizations has significant implications for participants' trust in data [159, 160, 161, 162]. It becomes even more relevant when the data communicates some kind of risk [163, 164]. This was also apparent in both of our studies. Mayr et al. [87] emphasize that trustworthiness is determined by both the attributes of the visualization and the reliability of the underlying data. For example, if a map is well-designed with clear labels and accurate data sources cited, users may find it trustworthy. In contrast, trust perception is the user's own assessment of the map's reliability. Therefore, users' perception of trust in the map might vary depending on their past experiences or biases. For instance, someone might trust a map from a reputable news outlet more than a map shared on social media. Our findings revealed that participant's subjective evaluation of trustworthiness was about (labeled) missing data, wondering about their absence. In Study 2, missing data decreased trust if, for example, data from marginalized or disadvantaged groups (or countries) was missing, and the visualization did not clarify why. Sacha et al. [162] introduce a trust model where visualization serves as a mediator between the propagation of uncertainty and the establishment of trust. In their study, they explore the perspectives of both viewers and designers on uncertainty in data. They assert that informing users about the existence of uncertainty in the data contributes to an increase in trust. This is in line with our results, as some participants of Study 2 also perceived labeled missing data as a sign of honesty and transparency. It reflected their trust in map designers to provide accurate and reliable information without manipulating or fabricating data. They appreciate the fact that certain data is simply unavailable. Other research parallels this finding, suggesting that trust can be enhanced if uncertainty is mentioned in the data [89, 165, 166, 167]. However, in other studies, an excess of transparency might adversely impact trust [89, 168], suggesting that a balance is required to convey uncertainty in data.

5.3. Limitations and future work

Effects of task design: In our study, the task design was intentionally open-ended, with no specific outcome in mind for participants. Our aim was to encourage free-style exploration of the maps, a common approach in the sensemaking of visualizations as seen in previous research [106,135,136]. However, we acknowledge that employing explicit tasks during the interaction could lead to differences in users' sensemaking processes. There could be a more focused assessment of participants' comprehension and understanding of the visualizations. This could provide valuable insights into how users interpret and interact with the map visualizations when given specific directions or objectives.

Effects of map visualization: In our study, we addressed ongoing crises that gradually expand their severe and drastic effects. This implies that the crises are evolving and becoming more severe over time. Future studies could focus on crisis matters that are not only dedicated to emergency response but also outline future predictions. During both studies, the maps were presented as standalone visualizations without the context of the articles in which they were originally published. Thus, we gained an understanding of how map visualizations are perceived without auxiliary means. Future researchers could explore how additional information influences participants' interpretation and perception of the crisis issues depicted in the maps. Additionally, contemporary online map visualizations often incorporate interactive features, allowing users to explore the data in various ways. While our studies focused on static visualizations, the dynamics of interactive visualizations may elicit different cognitive and affective responses from participants.

Effects of background information: Our findings cannot be generalized for all Digital Natives, as the participants in Study 1 primarily came from the US, while those in Study 2 were from European countries, particularly in German-speaking regions. Therefore, further research is needed to explore how Digital Natives with different age, educational, and cultural backgrounds interpret map-based crisis visualizations (published by the New York Times and beyond).

Effects of device: Our task design is specifically intended to encourage participants to engage naturally with the map. Therefore, our study aims to take place in participants' 'comfort zone' by conducting interviews from their homes or places, where they feel at ease. However, the use of participants' personal devices for remote participation in our interview study also introduced certain limitations, such as network problems, display resolution, and other environmental aspects in their homes. Prior research has indicated that these constraints could potentially lead to issues [60,169,170]. To gain deeper insights into the impact of devices, future studies should consider conducting more controlled laboratory experiments.

5.3. Limitations and future work

In addition to the mentioned areas of future work, there are several other avenues that researchers can explore to build upon the findings of our studies. One important direction is the development of design guidelines for maps depicting crisis topics. Combined with our insights and other research findings focusing on crisis visualizations, these guidelines could serve as valuable resources for creating more effective and user-friendly crisis visualizations. Furthermore, future studies could focus on investigating specific crisis topics in greater depth rather than addressing crises in general. By narrowing the scope to particular crisis issues, researchers can gain more nuanced insights into how different crisis topics impact users' understanding and their emotional responses.

5.4. Conclusion

In conclusion, this research sheds light on the importance of understanding crisis map visualizations in the context of news media. With the rapid spread of misinformation in times of crisis, accurate comprehension of these visualizations has become more essential than ever. We aim to uncover sensemaking activities and possible challenges that could harm proper comprehension of used crisis maps among Digital Natives. Through two qualitative studies, we retrieved a multistage sensemaking process, consisting of three interconnected sensemaking activity groups in the comment study: i) first impression, ii) deeper engagement, and iii) personal connection, and four in the interview study: i) visual impression, ii) conceptual meaning, iii) deeper engagement and iv) affective factors. These findings highlight the complexity of sensemaking and the interplay of how individuals interpret crisis visualizations. One key insight from our research is the significant role of personal connection to the topic in comprehending crisis visualizations effectively. The level of personal identification with the crisis issue and the geographical excerpt can impact the depth of interpretation and understanding. This underscores the need for creating visualizations that resonate with diverse audiences and evoke personal relevance. Additionally, our studies revealed challenges related to color concepts, the need for context, and the ambiguity of missing data, which can affect viewers' trust in the visualizations. Addressing these challenges is crucial to enhancing the reliability and credibility of crisis map visualizations. It is important to note that our research mainly focused on Digital Natives' sensemaking. To enhance our understanding of sensemaking activities concerning crisis visualization, further analysis of other lay audience groups' should be undertaken. Overall, this research contributes valuable insights into the sensemaking processes of crisis map visualizations and highlights the importance of user-centered design. By considering the diverse perspectives and information needs of the general public, we can ensure that crisis visualizations are impactful in informing the public about critical issues. Understanding how lay audiences interpret and respond to them is essential for fostering informed decision-making and public engagement.

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A. Appendix

A.1. WIGOITG visualizations overview

In our two studies, we draw upon graphics from the "What's going on in this graph" (WIGOITG) series by The New York Times¹. To acquire an initial comprehension of the types of graphics and the topics addressed within them, we compiled a list of all 119 visualizations published (until September 29, 2022), along with their statistical characteristics [171, 172] (see A.1, A.2 and A.3). The New York Times refers to these characteristics as "statistical nuggets" (right side of the table) [173]. Subsequently, we present an overview of all 23 'maps visualizations' published in this series. Here, we assign properties to the maps (following Munzner's framework [69]) and determine whether they qualify as crisis graphics or not (A.4).

All links to the visualizations were last checked on January 29, 2024, to ensure functionality and accuracy.

¹<https://www.nytimes.com/column/whats-going-on-in-this-graph>

A. Appendix

CHARACTERISTICS OF THE VISUALIZATIONS													STATISTICAL INDICATORS			
ID	published date	name	topic	link	# comments	type of chart	chart definition	variables	statistics	distribution	data collections	graph	math			
1	13.09.17	Horizon Map Get 50 richest of Russia. How long is Spain Healthy? What About Greenland? Where	Ever امنScience and Technology	https://www.nytimes.com/2017/09/13/learning/what-s-going-on-in-the-graph-sec-10-2017.html	550	Maps	General and Area Representations	Variable	Statistic			Histogram	Rate			
2	09.10.17	Americans and Nutrition on Diets: Upturn	Health and Wellness	https://www.nytimes.com/2017/10/09/learning/what-s-going-on-in-the-graph-sec-10-2017.html	307	Association	Point-based Bar Representations	Association Variable	Statistic			Scatter plot	Rate			
3	14.11.17	Unemployment (ISA 2009) Labor Shortage	United States EconomyPublic History and Civics	https://www.nytimes.com/2017/11/14/learning/what-s-going-on-in-the-graph-sec-13-2017.html	328	Time	Line-based Representations		Statistic		TOTAL US SUBGROUP STATISTICS	LineChart				
4	12.12.17	Real Jobs	United States EconomyPublic History and Civics	https://www.nytimes.com/2017/12/12/learning/what-s-going-on-in-the-graph-sec-13-2017.html	160	Time	Line-based Representations		Statistic			Scatter Graph	Percentage Change Rate			
5	04.01.18	Sex Matters About Choosing a Major	Education	https://www.nytimes.com/2018/01/04/learning/what-s-going-on-in-the-graph-sec-14-2018.html	442	Distribution	General and Bar Representations		Statistic			Bubble Chart				
6	08.02.18	What's About Love	The US Sports and Culture	https://www.nytimes.com/2018/02/08/learning/what-s-going-on-in-the-graph-sec-14-2018.html	None	Association	Point-based Bar Representations	Association Outlier	Statistic			Scatter plot	Rate			
7	08.03.18	International Commerce Signage and Answer	Global EconomicalPublic History and Culture	https://www.nytimes.com/2018/03/08/learning/what-s-going-on-in-the-graph-sec-13-2018.html	365	Association	Contour-based Representations	Variable	Statistic			Scatter plot	Rate			
8	03.04.18	What Music Do Americans Love the Most? 50	The US Sports and Culture	https://www.nytimes.com/2018/04/03/learning/what-s-going-on-in-the-graph-sec-14-2018.html	205	Maps	Point-based Representations		Statistic		MAP AS DEMAND DIVIATION	Heatmap	Number vs Amount			
9	03.05.18	Hotter	Ever امنScience and Technology	https://www.nytimes.com/2018/05/03/learning/what-s-going-on-in-the-graph-sec-14-2018.html	None	Distribution	Line-based Representations					Histogram	Rate			
10	14.05.18	The Prices in the U.S. When Oil Surges 5 Times	Ever امنScience and Technology	https://www.nytimes.com/2018/05/14/learning/what-s-going-on-in-the-graph-sec-13-2018.html	41	Time	General and Bar Representations	Association	Statistic			Bar Graph	Rate			
11	23.09.18	Deeper Agent Via Amazon Bankrupt	United States EconomyPublic History and Civics	https://www.nytimes.com/2018/09/23/learning/what-s-going-on-in-the-graph-sec-13-2018.html	118	Categories	General and Bar Representations		Statistic			Proportional Bar Graph	Length vs. Area of a Square			
12	02.10.18	With America's Intermediate Supreme Court	United States EconomyPublic History and Civics	https://www.nytimes.com/2018/10/02/learning/what-s-going-on-in-the-graph-sec-13-2018.html	120	Time	Line-based Representations	Variable	Statistic			LineChart	Rate			
13	09.10.18	Remembering George	United States EconomyPublic History and Civics	https://www.nytimes.com/2018/10/09/learning/what-s-going-on-in-the-graph-sec-13-2018.html	186	Time	Line-based Representations	Variable	Statistic		POPULATION and its SUBGROUPS or	LineChart	Percentage Change Rate			
14	16.10.18	Food, Then Came KFC	Health and Wellness	https://www.nytimes.com/2018/10/16/learning/what-s-going-on-in-the-graph-sec-13-2018.html	70	Association	Point-based Bar Representations	Variable	Statistic			Scatter plot	Percentage Change Rate			
15	18.10.18	The Most Healthy November	United States EconomyPublic History and Civics	https://www.nytimes.com/2018/10/18/learning/what-s-going-on-in-the-graph-sec-14-2018.html	69	Categories	Point-based Representations	Variable	Statistic			Scatter plot	Rate			
16	01.11.18	Highlights from a Very Detailed Map of the	United States EconomyPublic History and Civics	https://www.nytimes.com/2018/11/01/learning/what-s-going-on-in-the-graph-sec-13-2018.html	85	Maps	Map-based Representations		Percentil Statistic			Heatmap	Rate			
17	08.11.18	Paraphrase the Women Have Babies: New Age	The US Sports and Culture	https://www.nytimes.com/2018/11/08/learning/what-s-going-on-in-the-graph-sec-14-2018.html	209	Maps	Map-based Representations	Variable	Statistic			Directed Graph	Rate			
18	22.11.18	Divide America	Health and Wellness	https://www.nytimes.com/2018/11/22/learning/what-s-going-on-in-the-graph-sec-13-2018.html	126	Distribution	General and Bar Representations		Ratio Statistic			Histogram	Rate			
19	29.11.18	A Typical "Pioneer" Lives in Los Angeles? From	United States EconomyPublic History and Civics	https://www.nytimes.com/2018/11/29/learning/what-s-going-on-in-the-graph-sec-13-2018.html	94	Categories	General and Bar Representations		Statistic			Heatmap	Rate			
20	05.12.18	What's a 520? Show Actually Made You Buz	The US Sports and Culture	https://www.nytimes.com/2018/12/05/learning/what-s-going-on-in-the-graph-sec-13-2018.html	216	Categories	Point-based Bar Representations	Outlier	Statistic			Dot Plot	Percentage Change Rate			
21	09.01.19	A Recipe of Social Connections in America	Health and Wellness	https://www.nytimes.com/2019/01/09/learning/what-s-going-on-in-the-graph-sec-13-2019.html	279	Maps	General and Area Representations	Association Variable	Statistic			Map as Graph	Rate			
22	17.01.19	Most?	Ever امنScience and Technology	https://www.nytimes.com/2019/01/17/learning/what-s-going-on-in-the-graph-sec-13-2019.html	252	Time	Contour-based Representations		Statistic			Heatmap	Rate			
23	24.01.19	The Migration of America	United States EconomyPublic History and Civics	https://www.nytimes.com/2019/01/24/learning/what-s-going-on-in-the-graph-sec-13-2019.html	124	Time	Line-based Representations		Statistic			LineChart	Rate			
24	31.01.19	How a New Kind of Fog Is at Storm 2018	The US Sports and Culture	https://www.nytimes.com/2019/01/31/learning/what-s-going-on-in-the-graph-sec-13-2019.html	316	Point to Whole	General and Bar Representations		Ratio Statistic			Scatter plot	Rate			
25	07.02.19	Is America's Military Big Enough?	United States EconomyPublic History and Civics	https://www.nytimes.com/2019/02/07/learning/what-s-going-on-in-the-graph-sec-13-2019.html	509	Maps	Point-based Bar Representations	Variable	Statistic			Bubble Map	Rate			
26	21.02.19	Test the Rain	Health and Wellness	https://www.nytimes.com/2019/02/21/learning/what-s-going-on-in-the-graph-sec-13-2019.html	303	Categories	General and Bar Representations	Variable	Statistic			Bar Graph	Rate			
27	28.02.19	F.O.A. to Lift How to Get Sell: Maping Flavors	Health and Wellness	https://www.nytimes.com/2019/02/28/learning/what-s-going-on-in-the-graph-sec-13-2019.html	309	Time	General and Bar Representations		Statistic			Bar Graph	Rate			
28	07.03.19	What Do the State Maps Really Say?	Ever امنScience and Technology	https://www.nytimes.com/2019/03/07/learning/what-s-going-on-in-the-graph-sec-13-2019.html	264	Categories	General and Bar Representations		Statistic			Table	Rate			
29	14.03.19	Orlando's New Career: What's at Risk?	Education	https://www.nytimes.com/2019/03/14/learning/what-s-going-on-in-the-graph-sec-13-2019.html	278	Association	Point-based Bar Representations	Outlier Variable	Statistic			Scatter plot	Rate			
30	28.03.19	Artery Spring	Ever امنScience and Technology	https://www.nytimes.com/2019/03/28/learning/what-s-going-on-in-the-graph-sec-13-2019.html	330	Maps	General and Area Representations		Mathematical Statistic			Map as Graph	Mathematical Model Rate			
31	04.04.19	Do Summer's Sound the Same?	The US Sports and Culture	https://www.nytimes.com/2019/04/04/learning/what-s-going-on-in-the-graph-sec-13-2019.html	108	Categories	Line-based Representations	Outlier Variable	Ratio Statistic			Radial Chart	Algorithm Rate			
32	11.04.19	How to Get a New Map of the World: What the	The US Sports and Culture	https://www.nytimes.com/2019/04/11/learning/what-s-going-on-in-the-graph-sec-13-2019.html	146	Association	Point-based Bar Representations	Association Outlier	Statistic			Scatter plot	Rate			
33	12.09.19	Read a Map: What's the Right Way	Ever امنScience and Technology	https://www.nytimes.com/2019/09/12/learning/what-s-going-on-in-the-graph-sec-13-2019.html	362	Maps	General and Area Representations	Uncertainty	Statistic			Map as Graph	Uncertainty			
34	03.10.19	Where Education Drives Mobility	Education	https://www.nytimes.com/2019/10/03/learning/what-s-going-on-in-the-graph-sec-13-2019.html	399	Time	General and Bar Representations	Outlier Variable	Mathematical Statistic			Bar Graph	Rate			
35	10.10.19	Since 1880	Ever امنScience and Technology	https://www.nytimes.com/2019/10/10/learning/what-s-going-on-in-the-graph-sec-13-2019.html	278	Time	General and Area Representations	Variable	Ratio Statistic			Scatter plot	Percentage Change Rate			
36	24.10.19	Plummeted	Health and Wellness	https://www.nytimes.com/2019/10/24/learning/what-s-going-on-in-the-graph-sec-13-2019.html	279	Time	Line-based Representations	Variable	Ratio Statistic			LineChart	Rate			
37	31.10.19	How Popular is Baseball?	The US Sports and Culture	https://www.nytimes.com/2019/10/31/learning/what-s-going-on-in-the-graph-sec-13-2019.html	140	Association	Line-based Representations	Variable	Ratio Statistic			Scatter plot	Rate			
38	07.11.19	What's the Right Number of Jobs?	Ever امنScience and Technology	https://www.nytimes.com/2019/11/07/learning/what-s-going-on-in-the-graph-sec-13-2019.html	270	Time	Line-based Bar Representations	Variable	Statistic			Scatter plot	Rate			
39	14.11.19	How Much Physical Experience Does it Take to	United States EconomyPublic History and Civics	https://www.nytimes.com/2019/11/14/learning/what-s-going-on-in-the-graph-sec-13-2019.html	249	Time	General and Area Representations	Variable	Ratio Statistic			Scatter plot	Percentage Change Rate			
40	21.11.19	The Most Detailed Map of Air Emissions in	Ever امنScience and Technology	https://www.nytimes.com/2019/11/21/learning/what-s-going-on-in-the-graph-sec-13-2019.html												

Figure A.1.: Overview of the 'WIGOITG' visualizations - part 1/3

A.1. WIGOITG visualizations overview

CHARACTERISTICS OF THE VISUALIZATIONS							STATISTICAL INDICATORS						
ID	published date	name	topic	link	# comments	type of chart	chart definition	variables	statistics	distribution	data collections	graph	math
41	11.11.19	Underground Resistance and Crime Rate	United States Economy, Politics, History and Civics	https://www.nytimes.com/2021/11/26/learning/what-s-going-on-in-the-graph-the-11-2019.html	210	Association	Point-based Bar Representations	Association, Outlier	Statistic, TREND		Scatterplot	Bar Graph	Rate
42	13.12.19	Chungkingweird	Foreign Intelligence and Technology	https://www.nytimes.com/2021/12/05/learning/what-s-going-on-in-the-graph-the-13-2019.html	218	Comparing	Gene and Bar Representations	Variable	Link	Distribution		Bar Graph	Rate
43	28.02.20	Privacy Policies Are a Mess	Foreign Intelligence and Technology	https://www.nytimes.com/2020/02/28/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	445	Association	Point-based Bar Representations	Variable	Statistic		Scatterplot	Bar Graph	Percentage Point Difference vs. Percentage Difference
44	28.02.20	Inside Facebook's Campaign to Save the Game	The Arts, Sports and Culture	https://www.nytimes.com/2020/02/28/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	562	Comparing	Graph-based Representations	Variable	Bar, Statistic		Integrative Graph	Scatterplot	Rate
45	12.03.20	Wiley Post and Tamm's Journey Around the World	United States Economy, Politics, History and Civics	https://www.nytimes.com/2020/03/12/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	427	Comparing	Line-based Representations	Variable	Statistic	Distribution		Segmented Bar Graph	Margin Rate
46	13.03.20	The Major Cause of Mental Health	Health and Wellness	https://www.nytimes.com/2020/03/13/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	376	Part-to-Whole	Gene and Bar Representations	Variable	Model, Statistic	Distribution	Random Sample	Line Chart	Mathematical Model Rate
47	26.03.20	Why We Need to Keep the Curve Flat	Covid-19	https://www.nytimes.com/2020/03/26/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	1200	Other	Note-link		Statistic		Simulation	Line Chart	
48	03.04.20	You Can't Beat the Chain of Transmission	Covid-19	https://www.nytimes.com/2020/04/03/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	1000	Other	Tree of graphs, networks, tables		Statistic		Simulation	Tree Diagram	Exponential Growth Rate
49	16.04.20	What If We Open America Too Early?	Covid-19	https://www.nytimes.com/2020/04/16/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	437	Time	Line-based Representations	Variable	Uncertainty		Simulation	Bar Graph	Mathematical Model Rate
50	24.04.20	How the Virus Transformed How Americans	Covid-19	https://www.nytimes.com/2020/04/24/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	563	Association	Point-based Bar Representations	Variable	Statistic		Simulation	Bar Graph	Percentage Change Rate
51	24.04.20	Support Their Memory	United States Economy, Politics, History and Civics	https://www.nytimes.com/2020/04/24/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	563	Comparing	Point-based Bar Representations	Variable	Statistic		Simulation	Bar Graph	Percentage Change Rate
52	30.04.20	2023: What the Second Quarter Year-Covering	Foreign Intelligence and Technology	https://www.nytimes.com/2020/04/30/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	408	Time	Gene and Bar Representations	Variable	Statistic		Simulation	Bar Graph	Rate
53	07.05.20	Anti-Inflation Shift in U.S. Promoted Rate of a Young Fed Reserve	United States Economy, Politics, History and Civics	https://www.nytimes.com/2020/05/07/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	205	Time	Line-based Representations	Variable	Statistic		Simulation	Bar Graph	Rate
54	14.05.20	How Long Will a Vaccine Really 'Take'?	Covid-19	https://www.nytimes.com/2020/05/14/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	291	Part-to-Whole	Tree of graphs, networks, tables	Association	Statistic		Experiment	Tree Diagram	Rate
55	14.05.20	Is It Safe to Visit a Coffee Shop or a Gym?	Covid-19	https://www.nytimes.com/2020/05/14/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	230	Association	Point-based Bar Representations	Association, Variable	Statistic		Experiment	Bar Chart	Rate
56	09.06.20	Master of the Masked Bus Rides	United States Economy, Politics, History and Civics	https://www.nytimes.com/2020/06/09/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	463	Time	Line-based Representations	Variable	Statistic		Experiment	Bar Chart	Percentage Change Rate
57	10.06.20	Covid-19: Cases in America	Covid-19	https://www.nytimes.com/2020/06/10/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	385	Maps	Point-based Bar Representations		Statistic			Bar Chart	PERCENTAGE
58	17.06.20	Warner Moviehouse's Running Times	United States Economy, Politics, History and Civics	https://www.nytimes.com/2020/06/17/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	332	Comparing	Gene and Bar Representations	OUTLIER	LINE OF BEST FIT			SCATTERPLOT	WEIGHTED AVERAGE
59	24.06.20	Supporter's Wonders	United States Economy, Politics, History and Civics	https://www.nytimes.com/2020/06/24/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	411	Comparing	Gene and Bar Representations	OUTLIER				BAR CHART	
60	01.10.20	2020 U.S. Census	United States Economy, Politics, History and Civics	https://www.nytimes.com/2020/10/01/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	293	Time	Line-based Representations					TIME SERIES GRAPH	
61	08.10.20	Comparative Spending During the Pandemic	Covid-19	https://www.nytimes.com/2020/10/08/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	374	Comparing	Gene and Bar Representations					BAR CHART	
62	15.10.20	Climate Threats	Foreign Intelligence and Technology	https://www.nytimes.com/2020/10/15/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	414	Maps	Gene and Bar Representations					CHOICE, LETT, MAP	
63	22.10.20	World's Most Active	Global Economics, Statistics, Physics and Culture	https://www.nytimes.com/2020/10/22/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	345	Time	Line-based Representations	OUTLIER	TREND, LINE			INTEGRATIVE GRAPH	
64	29.10.20	Unemployment During the Pandemic	Covid-19	https://www.nytimes.com/2020/10/29/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	267	Comparing	Gene and Bar Representations					STACKED AREA GRAPH	
65	12.11.20	Thanksgiving Side Dishes	United States Economy, Politics, History and Civics	https://www.nytimes.com/2020/11/12/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	361	Maps	word-based					INTEGRATIVE GRAPH	PERCENTAGE DATA
66	03.11.20	2020 Presidential Election Maps	United States Economy, Politics, History and Civics	https://www.nytimes.com/2020/11/03/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	602	Maps	Gene and Bar Representations					TIME MAP	
67	03.12.20	World's Most Active	Covid-19	https://www.nytimes.com/2020/12/03/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	424	Comparing	Point-based Bar Representations					DOTPLOT	MEMBER, RATE
68	10.12.20	Instant Memory	United States Economy, Politics, History and Civics	https://www.nytimes.com/2020/12/10/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	324	Comparing	Gene and Bar Representations				ONLINE SURVEY	INTEGRATIVE GRAPH	
69	28.12.20	First Vice President	United States Economy, Politics, History and Civics	https://www.nytimes.com/2020/12/28/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	367	Comparing	Line-based Representations					TIME SERIES GRAPH	PERCENTAGE POINT & RATE
70	07.01.21	Working Shifts	United States Economy, Politics, History and Civics	https://www.nytimes.com/2021/01/07/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	278	Time	Gene and Bar Representations					BAR CHART	PERCENTAGE POINT & RATE
71	14.01.21	Memorial Day Race	United States Economy, Politics, History and Civics	https://www.nytimes.com/2021/01/14/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	135	Comparing	Gene and Bar Representations	MARGIN				BAR CHART	PERCENTAGE POINT & RATE
72	21.01.21	Climate-Friendly Cars	Foreign Intelligence and Technology	https://www.nytimes.com/2021/01/21/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	249	Comparing	Point-based Bar Representations					SCATTERPLOT	PERCENTAGE POINT & RATE
73	28.01.21	Diversity in Professional Sports	United States Economy, Politics, History and Civics	https://www.nytimes.com/2021/01/28/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	428	Time	Gene and Bar Representations					SCATTERPLOT	PERCENTAGE POINT & RATE
74	04.02.21	U.S. Air Pollution	Health and Wellness	https://www.nytimes.com/2021/02/04/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	411	Maps	Gene and Bar Representations					CHOICE, LETT, MAP	PERCENTAGE POINT & RATE
75	11.02.21	World's Most Active	Health and Wellness	https://www.nytimes.com/2021/02/11/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	378	Time	Line-based Bar Representations	QUANTITATIVE & CATEGORICAL				TIME SERIES GRAPH	PERCENTAGE POINT & RATE
76	25.02.21	Smoking & Income	Health and Wellness	https://www.nytimes.com/2021/02/25/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	444	Comparing	Gene and Bar Representations				ONLINE SURVEY	BAR CHART	PERCENTAGE POINT & RATE
77	04.03.21	Covid-19: Immunity	Covid-19	https://www.nytimes.com/2021/03/04/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	424	Time	Line-based Bar Representations					TIME SERIES GRAPH	PERCENTAGE POINT & RATE
78	11.03.21	Recent U.S. Development	United States Economy, Politics, History and Civics	https://www.nytimes.com/2021/03/11/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	189	Maps	Point-based Bar Representations					MAP AS A GRAPH	MATHEMATICAL MODEL
79	14.03.21	Weather-related Headlines	Covid-19	https://www.nytimes.com/2021/03/14/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	307	Comparing	Gene and Bar Representations					MAP AS A GRAPH	
80	23.03.21	Global Climate Risk	Foreign Intelligence and Technology	https://www.nytimes.com/2021/03/23/learning/what-s-going-on-in-the-graph-jan-7-9-2020.html	264	Maps	Gene and Bar Representations					MAP AS A GRAPH	

Figure A.2.: Overview of the 'WIGOITG' visualizations - part 2/3

A. Appendix

CHARACTERISTICS OF THE VISUALIZATIONS							STATISTICAL INDICATORS						
IO	published date	name	topic	link	# comments	type of chart	chart definition	variables	statistics	distribution	data collections	graph	math
81	01.04.21	Growing Zones	Environmental Science and Technology	https://www.nytimes.com/2021/04/01/learning/whats-gon-on-in-the-world-growing-zones.html	238 Maps	Generated Area Representations	AREA CT, INVERSE RELATIONSHIP	AVERAGE & VARIABILITY			SCATTERED CHART	SCATTERED MAP	TOTAL x PERCENT IN DATA
82	08.04.21	Global Life Expectancy & Health Expenditures	Health and Wellness	https://www.nytimes.com/2021/04/08/learning/whats-gon-on-in-the-world-global-life-expectancy-health-expenditures.html	311 Line Charts	Line-based Representations						SCATTERPLOT	
83	15.04.21	Global Electric Vehicle Turnover	Environmental Science and Technology	https://www.nytimes.com/2021/04/15/learning/whats-gon-on-in-the-world-global-electric-vehicle-turnover.html	471 Time Series	Generated Area Representations						MAFEE CHART	ABSOLUTE CHANGE and PERCENTAGE CHANGE FROM
84	22.04.21	First Remote Jobs	COVID-19	https://www.nytimes.com/2021/04/22/learning/whats-gon-on-in-the-world-first-remote-jobs.html	297 Comparing	Generated Area Representations			QUANTILE		SIMULATION	CONNECTED DOT	PERCENTAGE CHANGE FROM
85	29.04.21	COVID in Prisons	COVID-19	https://www.nytimes.com/2021/04/29/learning/whats-gon-on-in-the-world-covid-in-prisons.html	107 Line Charts	Line-based Representations						PIOT	PERCENTAGE CHANGES
86	11.05.21	Travel about Inequality	United States Economy/Political Economy and Civics	https://www.nytimes.com/2021/05/11/learning/whats-gon-on-in-the-world-travel-about-inequality.html	21 Time Series	Line-based Representations						PIOT	
87	13.05.21	President Biden's Economic Plan	United States Economy/Political Economy and Civics	https://www.nytimes.com/2021/05/13/learning/whats-gon-on-in-the-world-president-biden-s-economic-plan.html	279 Comparing	Generated Area Representations						PIOT	
88	09.09.21	Pandemic Change	COVID-19	https://www.nytimes.com/2021/09/09/learning/whats-gon-on-in-the-world-pandemic-change.html	1,100 Time Series	Generated Area Representations						PIOT	
89	16.09.21	Normal U.S. Precipitation	Environmental Science and Technology	https://www.nytimes.com/2021/09/16/learning/whats-gon-on-in-the-world-normal-us-precipitation.html	462 Maps	Generated Area Representations	AREA MAP					SCATTERPLOT	PERCENTAGE CHANGE
90	23.09.21	Covid Hospitalizations	COVID-19	https://www.nytimes.com/2021/09/23/learning/whats-gon-on-in-the-world-covid-hospitalizations.html	424 Time Series	Line-based Representations	AREA MAP					SCATTERPLOT	
91	30.09.21	Climate-Change-Related Deaths	United States Economy/Political Economy and Civics	https://www.nytimes.com/2021/09/30/learning/whats-gon-on-in-the-world-climate-change-related-deaths.html	516 Time Series	Other						SCATTERPLOT	
92	07.10.21	Shape "mystery food pair"	Health and Wellness	https://www.nytimes.com/2021/10/07/learning/whats-gon-on-in-the-world-shape-mystery-food-pair.html	317 Comparing	Bar-based Representations	AREA MAP					SCATTERPLOT	
93	14.10.21	Pandemic's Effect on Climate Change	COVID-19	https://www.nytimes.com/2021/10/14/learning/whats-gon-on-in-the-world-pandemic-s-effect-on-climate-change.html	465 Time Series	Bar-based Representations	AREA MAP					SCATTERPLOT	
94	21.10.21	Wind & Solar Power	Environmental Science and Technology	https://www.nytimes.com/2021/10/21/learning/whats-gon-on-in-the-world-wind-solar-power.html	411 Maps	Point-based Representations	AREA MAP					SCATTERPLOT	
95	04.11.21	Scoring Gun Murders	United States Economy/Political Economy and Civics	https://www.nytimes.com/2021/11/04/learning/whats-gon-on-in-the-world-scoring-gun-murders.html	323 Comparing	Line-based Representations	ASSOCIATION					SCATTERPLOT	
96	11.11.21	Supply Chain Disrupts	Global Economy/Political Economy and Culture	https://www.nytimes.com/2021/11/11/learning/whats-gon-on-in-the-world-supply-chain-disrupts.html	488 Other	Line-based Representations	ASSOCIATION					SCATTERPLOT	
97	18.11.21	Global Carbon Emissions	Environmental Science and Technology	https://www.nytimes.com/2021/11/18/learning/whats-gon-on-in-the-world-global-carbon-emissions.html	428 Comparing	Line-based Representations						SCATTERPLOT	
98	02.12.21	Drawing Voting Maps	United States Economy/Political Economy and Civics	https://www.nytimes.com/2021/12/02/learning/whats-gon-on-in-the-world-drawing-voting-maps.html	562 Comparing	Point-based Representations						SCATTERPLOT	
99	09.12.21	College Exits	United States Economy/Political Economy and Civics	https://www.nytimes.com/2021/12/09/learning/whats-gon-on-in-the-world-college-exits.html	559 Comparing	Point-based Representations						SCATTERPLOT	
100	06.01.22	Vaccination by Country	COVID-19	https://www.nytimes.com/2022/01/06/learning/whats-gon-on-in-the-world-vaccination-by-country.html	476 Distribution	Category-based Representations	ASSOCIATION					SCATTERPLOT	
101	13.01.22	Reproduction Diversity Shift	United States Economy/Political Economy and Civics	https://www.nytimes.com/2022/01/13/learning/whats-gon-on-in-the-world-reproduction-diversity-shift.html	170 Maps	Category-based Representations						SCATTERPLOT	
102	20.01.22	Asian Population	United States Economy/Political Economy and Civics	https://www.nytimes.com/2022/01/20/learning/whats-gon-on-in-the-world-asian-population.html	308 Maps	Category-based Representations						SCATTERPLOT	
103	27.01.22	Clean Energy Milestones	United States Economy/Political Economy and Civics	https://www.nytimes.com/2022/01/27/learning/whats-gon-on-in-the-world-clean-energy-milestones.html	313 Comparing	Generated Area Representations						SCATTERPLOT	
104	03.02.22	International Optimism	Global Economy/Political Economy and Culture	https://www.nytimes.com/2022/02/03/learning/whats-gon-on-in-the-world-international-optimism.html	341 Comparing	Point-based Representations						SCATTERPLOT	
105	10.02.22	Weddings	United States Economy/Political Economy and Civics	https://www.nytimes.com/2022/02/10/learning/whats-gon-on-in-the-world-weddings.html	286 Time Series	Line-based Representations						SCATTERPLOT	
106	24.02.22	Olympics Medal Count	Global Economy/Political Economy and Culture	https://www.nytimes.com/2022/02/24/learning/whats-gon-on-in-the-world-olympics-medal-count.html	242 Comparing	Line-based Representations						SCATTERPLOT	
107	10.03.22	Extreme Temperatures	Environmental Science and Technology	https://www.nytimes.com/2022/03/10/learning/whats-gon-on-in-the-world-extreme-temperatures.html	313 Maps	Line-based Representations						SCATTERPLOT	
108	17.03.22	Madness from the Line	Global Economy/Political Economy and Culture	https://www.nytimes.com/2022/03/17/learning/whats-gon-on-in-the-world-madness-from-the-line.html	334 Distribution	Point-based Representations						SCATTERPLOT	
109	24.03.22	Initiation Words	United States Economy/Political Economy and Civics	https://www.nytimes.com/2022/03/24/learning/whats-gon-on-in-the-world-initiation-words.html	244 Comparing	Word-based Representations						SCATTERPLOT	
110	31.03.22	Endangered Biodiversity	Environmental Science and Technology	https://www.nytimes.com/2022/03/31/learning/whats-gon-on-in-the-world-endangered-biodiversity.html	385 Maps	Category-based Representations						SCATTERPLOT	
111	07.04.22	Pandemic's Effects	COVID-19	https://www.nytimes.com/2022/04/07/learning/whats-gon-on-in-the-world-pandemic-s-effects.html	372 Comparing	Category-based Representations						SCATTERPLOT	
112	14.04.22	U.S. Population Dynamics	United States Economy/Political Economy and Civics	https://www.nytimes.com/2022/04/14/learning/whats-gon-on-in-the-world-us-population-dynamics.html	226 Time Series	Line-based Representations						SCATTERPLOT	
113	21.04.22	First Speech	United States Economy/Political Economy and Civics	https://www.nytimes.com/2022/04/21/learning/whats-gon-on-in-the-world-first-speech.html	293 Comparing	Bar-based Representations						SCATTERPLOT	
114	28.04.22	Winter Summers	Environmental Science and Technology	https://www.nytimes.com/2022/04/28/learning/whats-gon-on-in-the-world-winter-summers.html	214 Data Analysis	Line-based Representations						SCATTERPLOT	
115	05.05.22	Then Behaviors	United States Economy/Political Economy and Civics	https://www.nytimes.com/2022/05/05/learning/whats-gon-on-in-the-world-then-behaviors.html	265 Comparing	Line-based Representations						SCATTERPLOT	
116	08.09.22	Severe Weather's Record and Legacy	United States Economy/Political Economy and Civics	https://www.nytimes.com/2022/09/08/learning/whats-gon-on-in-the-world-severe-weather-s-record-and-legacy.html	884 Time Series	Line-based Representations						SCATTERPLOT	
117	15.09.22	Three Things and Climate	Environmental Science and Technology	https://www.nytimes.com/2022/09/15/learning/whats-gon-on-in-the-world-three-things-and-climate.html	679 Time Series	Line-based Representations						SCATTERPLOT	
118	22.09.22	American Morning	United States Economy/Political Economy and Civics	https://www.nytimes.com/2022/09/22/learning/whats-gon-on-in-the-world-american-morning.html	619 Time Series	Line-based Representations						SCATTERPLOT	
119	29.09.22	Calling for Climate Action	United States Economy/Political Economy and Civics	https://www.nytimes.com/2022/09/29/learning/whats-gon-on-in-the-world-calling-for-climate-action.html	743 Maps	Category-based Representations						SCATTERPLOT	

Figure A.3.: Overview of the 'WIGOITG' visualizations - part 3/3

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Figure A 4 : Overview of the 'WIGOUTG' visualizations - only n

A. Appendix

A.2. Map visualizations of the comment study

In our commentary study, we reference graphics published by the New York Times. The subsequent figure (A.5) provides an overview of the selected maps, while the accompanying table (A.1) lists the corresponding map links. This data was sourced from the New York Times website [171, 172].

ID	published date	name of the map	crisis topic	map section	type of map	variable(s)
1	29.09.2022	Which elected officials should do more on climate change?	political crises	USA	divergently ordered color map	Percentage of americans who think their elected leaders should do more to address global warming
2	31.03.2022	Endangered Biodiversity	biodiversity crises	USA	sequential ordered color map	Concentration of imperiled biodiversity
3	10.03.2022	Extreme Temperatures	climate change	USA	proportional symbol map	Heat waves: All time temperature record broken (in Fahrenheit)
4	28.10.2021	Wind & Solar Power	energy crises	USA	categorical color map	occurrence of wind and solar energy resources
5	16.09.2021	Normal U.S. Precipitation	climate change	USA	divergently ordered color map	precipitation compared with 20th century average in percent
6	01.04.2021	Growing Zones	agricultural crises	USA	categorical color map	hardiness zones
7	23.03.2021	Global Climate Risks	climate change	global	categorical color map	climate risks - seven variables
8	04.02.2021	Air Pollution	pollution crisis	USA	sequential ordered color map, divergently ordered color map	Absolute number of deaths due to air pollution
9	15.10.2020	Climate Threats	climate change	USA	categorical color map	Climate risks - six variables
10	10.09.2020	Covid-19 Cases in America	covid19	USA	proportional symbol map, sequential ordered color map	Absolute Numbers of Covid Cases
11	16.01.2020	Water Stress Levels	water stress	global	sequential ordered color map	Waterstress levels: low, medium, medium to high, high, extremely high
12	09.01.2020	North American Bird Populations	biodiversity crises	north america	categorical color map	Bird population (Tundra, Western forests, Grasslands, Arid lands, Eastern forests, Boreal forests)
13	19.09.2019	change in the population	demographical crises	USA	divergently ordered color map	Percentual change of the working-age population in the States

Figure A.5.: Overview of all map visualizations and their properties used for the comment study

A.2. Map visualizations of the comment study

Table A.1.: Links of all 13 visualizations

visualization	title	link
VIS1	Which elected officials should do more on climate change?	Link1
VIS2	Endangered Biodiversity	Link2
VIS3	Extreme Temperatures	Link3
VIS4	Wind and Solar Power	Link4
VIS5	Normal U.S. Precipitation	Link5
VIS6	Growing Zones	Link6
VIS7	Global Climate Risks	Link7
VIS8	Air Pollution	Link8
VIS9	Climate Threats	Link9
VIS10	Covid-19 Cases in America	Link10
VIS11	Water Stress Levels	Link11
VIS12	North American Bird Populations	Link12
VIS13	Change in the population	Link13

A.3. Ethical submission

The interviews were conducted in May and June 2023 via Zoom. The study received ethical approval from the University of Vienna's ethics committee, under reference number 0093. The positive decision from the ethics committee along with the application submission, is detailed below.

Beschluss der Ethikkommission
Decision of the Ethics Committee



Antragsteller*in / Applicant: **Laura Koesten, MSc Ph.D.**
Bearbeitungsnummer / Reference Number: **00937**
Projekttitel / Title of Project: **Understanding Map Visualisations of Crisis Issues**

Die Stellungnahme der Ethikkommission erfolgt aufgrund folgender eingereichter Unterlagen / The decision of the Ethics Committee is based on the following documents:

26.01.2023

- Information_for_participants_and_declaration_of_consent_Koesten_Starchenko
- Koesten_Starchenko_WS22_Ethics_application

06.02.2023

- 00937_Interview_Leitfaden_Starchenko_Koesten

04.05.2023

- (Deutsch) Information_for_participants_and_declaration_of_consent_Koesten_Starchenko
- May_2021_Application_Form_Ethics_Committee_Koesten_Starchenko_signed
- Refined-Information_for_participants_and_declaration_of_consent_Koesten_Starchenko

Die Kommission fasst folgenden Beschluss (mit X markiert) / The Ethics Committee has made the following decision (marked with an X):

☒ Zustimmung: Es besteht kein ethischer Einwand gegen die Durchführung der Studien. / Consent: There is no ethical objection to conduct the study as proposed.

☐ Negative Beurteilung: Der Antrag wird von der Ethikkommission abgelehnt. / Negative evaluation: The proposal is rejected by the Ethics Committee.

Inhaltliche Abänderungen müssen der Ethikkommission vorgelegt werden. / Amendments to the content must be presented to the Ethics Committee.

Unterschrift / Signature



Datum / Date

08.05.2023

Vorsitzender der Ethikkommission / Chair of the Ethics Committee
Univ.-Prof. MMag. DDr. Martin Voracek

A. Appendix

Application form for the assessment of planned academic studies by the Ethics Committee of the University of Vienna

May 2021

Please enclose the study proposed. In addition (!) to your brief answers (no more than 150 words) to the following questions, you can refer to the relevant section in the application form.

Please use not applicable (n/a) for points that do not apply.

The Ethics Committee points out that it will only process applications that fulfil all formal requirements. If additions are necessary due to formal reasons or if certain information has not been provided (e.g. questionnaires), the application will be processed at a later meeting.

1. General information

1.1. Name of the applicant

Dr. Laura Koesten

1.2. Title of the study

Understanding Map Visualisations of Crisis Issues

1.3. The study submitted is:

☐ a third-party-funded project

☐ proposal submitted

☐ already approved

Funding body/internal university project number/cost centre (if available):

☐ an internal university project

☐ a doctoral thesis (PhD thesis)

Name of the supervisor:

The supervisor was notified about the submission

☐ Yes

☐ No

Date of the successful completion of the public presentation at the faculty

☒ a master's thesis/diploma thesis

Name of the supervisor:

Dr. Laura Koesten, Dr. Kathleen Gregory, Prof Torsten Möller

Application for submission made by:

☒ Supervisor

☐ Body responsible for study matters

1.4. Why and/or for what purpose do you need a vote of the Ethics Committee?

☐ The study could threaten the research subject's physical and psychological integrity, the right to privacy, other subjective rights or other prevailing interests.

2

☐ A publication medium demands the vote of the Ethics Committee.

☐ A funding body demands the vote of the Ethics Committee.

☒ Other reasons, namely:

There is a potential request by publishing venue.

1.5. Has an ethics committee already evaluated this study?

☐ Yes

☒ No

If yes, please enclose the relevant report.

2. Brief information about the planned study

2.1. Is the planned study part of a larger research project? If yes: Please specify the title of this larger research project.

No

2.2. Academic discipline

Computer Science / Data Visualization and Data Analysis / HCI (= Human Computer Interaction)

2.3. Brief description of the planned study (no more than 500 words)

This interview study investigates how people make sense of common data visualisations of thematic maps about crisis issues and how such visualisations could be improved to enhance their comprehensibility and expressiveness. The project aims at conducting a semi structured interview study with approximately 20 participants to investigate their perspective and opinions on data visualisations in the context of crisis issues and peoples' sense-making techniques. In the course of the study, we conduct one interview with each participant, which can be held either remote or in-person according to participants preferences as well as COVID-19 regulations. Participants should be over 18 years old and fluent in the German or English Language. No additional qualifications are required. During the interview, the participants will briefly be asked about their background related to data visualisation and communication science. We will then ask them questions about crisis map visualisations and how people make sense of them. There is no right or wrong answer, we are solely interested in the participants' opinion on these topics and on the visualisations. Our conversation will be audio recorded. In total, this will take approximately 40 - 60 minutes. The interview questions of the study are structured into three overall themes: Demographic Information, general visualisation questions and map specific insights. All in all, this study aims at how map visualisations are used to communicate crisis aspects and how people make sense of such visualisations, especially thematic maps. This is a solely qualitative study. The findings of this qualitative data analysis are then used to derive implications for the creation and interpretation of crisis data visualisations. Thematic Maps referring to crisis issues covered in this study will discuss climate change, covid19 and economical aspects.

2.4. Objectives of the study (academic questions, hypotheses, etc.)

This exploratory study investigates how people make sense of common data in map visualisations about crisis issues covering climate change, covid19 and economical aspects. The objective is to contribute on how such visualisations could be improved to enhance their comprehensibility and expressiveness.

A. Appendix

2.5. Academic and social relevance of the study

The results of this study will help to provide important insights concerning map visualisations in the context of crisis. It is hoped that this research will add to the currently existing knowledge of how crisis map visualisations are understood by people and can inform the development of tools that can help create, work with or interpret map visualisations.

2.6. Description of the research design (e.g. survey dates, control groups, number of groups, estimated sample size, sampling, etc.)

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. Interviews are supposed to take place over a period of 2 to 4 weeks with an estimated sample size of approximately 20 respondents. Participants should be over 18 years old and fluent in the German or English Language. No additional qualifications are required. Participants are chosen based on their educational background, using purposive and snowball sampling. The interview will be audio-recorded. In total, this will take approximately 40 - 60 minutes. The recordings will be treated with the strictest confidentiality and will be destroyed after they have been transcribed. The Transcription process will be executed immediately after the interviews have been recorded. This process will take approximately one to two days.

2.7. Description of the data collection method, the sample (participants in the study), materials used for the study (e.g. instruments used), etc.

In the course of the study, we are planning to conduct semi-structured in-person or remote interviews (audio recorded) with participants of different educational backgrounds. The recordings will be treated with the strictest confidentiality and will be destroyed after they have been transcribed. The Transcription process will be executed immediately after the interviews have been recorded. This process will take approximately one to two days. Following types of personal data are gathered in the context of the interviews: age, educational background, personal experience in relevant areas of visualisation communication (type of experience, different areas). This data is only transcribed and used if it does not reveal the participants' identity. Answering any question is voluntary.

2.8. Planned start and expected duration of the study

Please note: The Ethics Committee does not evaluate projects that have already started or that have already been completed.

01.04.2023 (or as soon as ethical approval has been given) - 30.09.2023 (expected duration: 6-9 months)

3. Participants in the study

3a Recruitment of participants and inclusion and exclusion criteria for participating in the study

3.1. Planned number of participants

approximately 20 Participants

3.2. Expected duration of participation in the study

A.3. Ethical submission

40 - 60 minutes

3.3. Characterisation of participants

- Minimum age: 18 Maximum age: n/a
- Gender: ☒ male ☒ female ☒ diverse
- Does the study include persons who are not able to give their consent personally? ☐ Yes ☒ No
- Are the participants children or other vulnerable persons?

No

3.4. Please outline the planned recruitment procedure (attach all the material used for that purpose, such as advertisements):

Participants will be recruited from a variety of sources: snowball and purposive sampling from the extended network of the investigator and supervisors, postings via social media channels, Emails to authorities asking them to forward information about the study (Ministry of Labor, Austrian Chamber of Commerce) and potentially personal auditions by the investigator at specific work sites.

3.5. Briefly outline the selection of participants as well as inclusion and exclusion criteria (if applicable: provide specific reasons for the inclusion of individuals from protected groups, such as minors, individuals who are temporarily or permanently not able to give their consent).

Inclusion criteria: Participants will be selected according to their educational background, should be over 18 years old and fluent in the German or English Language. Exclusion criteria: Participants who do not fulfil the inclusion criteria or who are self reported experts in data visualisation will be excluded from the study.

3.6. Will you obtain the consent from the participants or from their legal representatives?

☒ Yes (please include information sheets and the declaration of consent)

☐ No If no, why not:

3.7. What is the relationship (personal, social, institutional) between the participants in the study and the persons carrying out the study (e.g. student-teacher, employee-employer, etc.)? Can you guarantee that the consent to participating in the study is given voluntarily?

We will use the existing networks as a starting point for snowball and purposive sampling. Participants will be informed that they are under no obligation to participate in the study and that they can withdraw at any time. The trial leader conducting the study will not interview any participants with which she has a relationship such as that of an employer/employee. A consent form that includes this information has to be signed by the participants in advance.

3b Data protection

Please distinguish between anonymisation and pseudonymisation!

Anonymisation means to render it irreversibly impossible to associate data with a person. For this reason, anonymous and anonymised data are outside the remit of data protection laws.

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Pseudonymisation means that it is possible, with the help of additional information (typically an identification key) to associate personal data with a person (see Art 4(5) General Data Protection Regulation). Pseudonymised data are within the remit of data protection laws.

- 3.8. What types of personal data (i.e. information that relate to an identified or identifiable natural person) will be collected?

We are planning to collect basic demographic information as well as information related to the specific educational background of the participant, like for example age, type of educational background, experience with visualisations. Furthermore, contact information such as mail address (a11928744@unet.univie.ac.at) and telephone number (+43-681-20-86-23-19), which are, however, only used for contacting and are stored separately from the study data.

- 3.9. How will you guarantee the anonymity of the participants?

Participants will not be directly identified in any reports of the research. The recordings will be treated with the strictest confidentiality and will be destroyed after they have been transcribed. The Transcription process will be executed immediately after the interviews have been recorded. This process will take approximately one to two days. 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). After the evaluation of the data the identification key of the assigned IDs is permanently deleted. The data is then permanently stored in anonymized form.

- 3.10. If a complete anonymisation of personal data is not possible: How will the privacy of participants be protected?

Only necessary and minimum demographic data will be presented in a participant table in order to avoid identification of participants in reported results. Participants will never be mentioned by name, without exception. Information or statements that might reveal the participants identity (e.g. name, institution/place of employment, etc.) are not transcribed. There will be an overview of how many and what type of participants took part in the study, however, this does not contain any information that could be indicative of the participants' 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, the participant will be contacted whether the participant agrees 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.

- 3.11. Will you make voice recordings or videos, or take pictures?

☒ Yes ☐ No

If yes: Will you ask participants to give their consent to the recordings, videos and pictures?

Participants will be asked in advance if they consent to audio recordings of the interview. Furthermore, the participants are informed in a participant information sheet that taking part in the study involves audio recording which will be transcribed, stored password protected and then destroyed after being transcribed for the purposes set out in the information sheet. The Transcription process will be executed immediately after the interviews have been recorded. This process will take approximately one to two days. A consent form that includes this information has to be signed by the participants in advance.

A.3. Ethical submission

- 3.12. How will you guarantee that participants can discontinue their participation in the study at any time?

The participants will be informed in a participant information sheet that their participation is voluntary and they may withdraw their participation for any reason at any time. A consent form that includes this information has to be signed by the participants in advance. A short briefing at the start of the interview, before recording starts, will ensure to remind participants of their right to withdraw or not answer certain questions.

- 3.13. How will the data collected during the study be processed and analysed?

☐ person-related, reason:

☒ indirectly related to the person

How will the data be anonymised?

Contact information and name will be provided with an ID and will not be stored in conjunction with the study data. Participants are asked for their consent to record the session. Only members of the research team, who are obliged to maintain secrecy, can access the data. After the recordings are transcribed, the recordings are deleted. The Transcription process will be executed immediately after the interviews have been recorded. This process will take approximately one to two days. The Participants data will be pseudonymised (through the allocation of an ID number, under which the data will be saved). After the evaluation of the data the identification key of the assigned IDs is permanently deleted. The data is then permanently stored in anonymized form. The participants' contact information will not be shared with anyone else without explicit permission.

Note: Please note that, in consideration of data protection, we recommend to use only anonymised data.

- 3.14. Where, in what form and for how long will the following data be recorded and/or stored? Who can access these data?

a. Declaration of consent

The data will be password protected and stored on university servers. Only members of the research team can access the data.

b. Study data (data collected as part of the relevant study)

The recordings will be treated with the strictest confidentiality and will be destroyed after they have been transcribed. The Transcription process will be executed immediately after the interviews have been recorded. This process will take approximately one to two days. The participants' contact information will be stored separately to the transcripts and will not be shared with anyone else without permission. The results of the data gathered will be analysed and can be presented at scientific conferences, and/or published in conference proceedings or journals.

c. Case history questionnaires (if available)

n/a

d. Human samples (e.g. blood samples, saliva samples) (if available)

n/a

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- 3.15. If study data are *not* stored in anonymised or pseudonymised form: When is this the case and what are the reasons?

Each participant will be assigned an ID and only that will be stored in the actual research data. After the evaluation of the data the identification key of the assigned IDs is permanently deleted. The data is then permanently stored in anonymized form. We discourage participants from disclosing personal or sensitive information. In any case quotes will only be published in a way that assures to not reveal the participants identity, unless explicit consent is given.

- 3.16. What security measures will you take to protect the participants' data against unauthorised access? (e.g. virus protection/firewall, individual log-in and password protection, administration of permissions, encrypted systems, electronic access control system, security doors).

Firewall and password protection. Data will be stored securely on University recommended servers; when necessary, identifiable information will be stored separately from other study data and participant quotes will only be published in a way that doesn't reveal the participants identity, unless explicit consent is given.

- 3.17. How can participants in the study access their personal study data?

A transcript of the recorded interview will be sent to the participants after the interview upon request, which is communicated in the participant information sheet.

- 3.18. Can participants obtain information about the research results?

☒ Yes ☐ No If no, reason:

Participants will be informed that they can request both a transcript as well as information about the results which will be given to them via email.

- 3.19. How and for how long can participants request the erasure of their study data?

Participants can request deletion of the data for up to two weeks after the interview took place with an informal request, e.g. via email, without giving a reason, which is specified in the participant information sheet.

3c Consequences for participants in the study

- 3.20. Is participating in the study associated with foreseeable risks or other foreseeable problematic side effects (e.g. pain, discomfort or violations of personal integrity)? What measures to you take to prevent and/or take care of unforeseeable/unwanted side effects?

No, participants are questioned about common data visualisations regarding their opinions and preferences. No risks are known for participants in this study.

- 3.21. What procedures will you apply to identify, document and report on unwanted effects of participating in the study? Please describe who will take care of it and when and how this will happen, e.g. interviews and/or based on lists of questions.

Participants will be briefed before recording starts that they can stop participation at any time, without giving a reason.

- 3.22. Will participants receive an attendance or expense allowance (compensation for travel expenses and loss of earnings)?

No.

- 3.23. What advantages and/or possible benefits can participants in the study expect?

The participants do not gain any direct benefits from participating in this study. Indirect benefits could include learning about map visualisations.

3d Additional ethical aspects

- 3.24. Will participants be fully informed about the type, objectives and content of the study?

☒ Yes ☐ No, reason:

Will participants be deceived?

☐ Yes ☒ No

If yes: Description and reason why it is necessary to deceive the participants:

- 3.25. In your opinion, are there any other potential problems regarding participation in and implementation of the study?

No.

- 3.26. What is the relation between the potential risks of participating in the study and the expected academic and social benefits?

No risks or benefits are known for participants in this study. We hope that the results of this study will provide important insights concerning data visualisations of maps in the context of crisis issues. It is hoped that this research will add to the currently existing knowledge of how visualisations depicting crisis issues (concerning climate change, covid19 and economy) are understood by people and can aid in developing useful tools that help working with and interpreting data visualisations of thematic maps.

- 3.27. Under what circumstances will the study be interrupted? Under what circumstances will the study be terminated entirely?

We do not anticipate that the study will be interrupted. Interviews can be conducted remotely, in order to accommodate a variety of participants and situations. In the event that participants raise serious complaints and interrupt the study, the design of the study will be revisited.

4. Other notes

n/a

A. Appendix

5. Persons carrying out the study

Please list all persons working on the study:

If applicable, please distinguish between the functions of project leader (leader of the entire project), study leader (leader of a partial study) and trial leader (carrying out a study). Make sure to clearly distinguish between these different functions and responsibilities in the information provided to participants and the declaration of consent.

Name	Institution	Function*	Qualification**
Sandra-Maria Starchenko	University of Vienna	trial leader (planning, analysis, collection of data)	Masters student
Dr Laura Koesten	University of Vienna	project leader	PhD, Postdoctoral researcher
Dr Kathleen Gregory	University of Vienna	project leader	PhD, Postdoctoral researcher
Prof. Torsten Möllner	University of Vienna	project leader	Univ.-Prof., PhD, Head of Research Group

* e.g. study leader, project leader, trial leader, planning, analysis, collection of data

** e.g. senior researcher, doctoral candidate, postdoctoral candidate, etc.

Are there any conflicts of interest between the researchers involved?

☐ Yes ☒ No

If yes: Complete the supplementary form on a conflict of interest and enclose it.

6. Name and signature of the applicant

6. Name and signature of the applicant

Name: Dr Laura Koesten
Institution/company: University of Vienna
Position: Postdoctoral researcher

Signature of the applicant: I herewith confirm that all the information regarding the planned study provided in this application is correct and that the study will be carried out in accordance with this information and pursuant to the code of good academic practice.

I declare that I will not start the empirical part of the submitted study (recruitment, collection of data) before obtaining the vote of the Ethics Committee.



, 20.03.23

Signature of the applicant, date

6.1. Person authorised to receive notifications

Laura Koesten, Kathleen Gregory, Sandra Starchenko

A.4. Information for participants

Potential participants were initially reached out through email and received a comprehensive participant information document, available in the subsequent sections. This document outlines the study's objectives, methodology, potential advantages, associated risks, participants' rights, and data collection policies. Any additional inquiries from participants were addressed through email correspondence or during pre-interview discussions. Prior to the recorded interviews, participants were requested to formally acknowledge their comprehension of the provided information by signing a consent declaration.

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

Understanding Map Visualisations of Crisis Issues

Dear participant,

We would like to invite you to participate in the study “Understanding Map Visualisations of Crisis Issues”. This exploratory study investigates how people make sense of common data in map visualisations about crisis issues covering climate change, covid19 and economical aspects. The objective is to contribute on how such visualisations could be improved to enhance their comprehensibility and expressiveness.

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 study is necessary to gain new, *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 visualisations of thematic maps covering crisis issues as climate change, covid19 and economics.

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. Participants should be over 18 years old and fluent in the English or German Language. No additional qualifications are required.

During the interview, you will briefly be asked about your background related to data visualisation. We will then ask you questions about crisis map visualisations and how people make sense of them. There is no right or wrong answer, we are solely interested in your opinion on these topics

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Understanding Map Visualizations of Crisis Issues – Information for participants and declaration of consent

and on the visualisations. 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 crisis data visualisations of thematic maps are understood by people and can aid in developing useful tools that help to work with and interpret data visualisations.

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

There are no known risks to you if you participate in this study.

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

There are no further implications or obligations for you as a result of participating in this study.

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

If you don't feel comfortable during the interview, you can stop participation at any time without giving a reason.

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

You can decide on your own if you want to stop participation. You can do this at any time without giving a reason.

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

The audio recordings will be treated with the strictest confidentiality and will 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 confidentiality, 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, only members of the research team are able to deduce any information about your person. After the evaluation of the data the identification key of the assigned IDs is permanently deleted. The data is then permanently stored in anonymized form. Standard demographic data such as gender, age, job title/activity are collected. In addition, the e-mail address and name will be deleted permanently after evaluating your audio recording, so your data is anonymized permanently.

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 participants took part in the study, however,

A.4. Information for participants

Understanding Map Visualizations of Crisis Issues – Information for participants and declaration of consent

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: age, educational background, personal experience in relevant areas of visualisation communication (type 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 request the deletion of your interview data for up to two weeks after the interview took place with an informal request, e.g. via email to Sandra-Maria Starchenko (a11928744@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: a11928744@unet.univie.ac.at

Trial Leader	Name: Sandra-Maria Starchenko E-mail: a11928744@unet.univie.ac.at Phone: +43-681-20-86-23-19
Project Leader	Name: Dr. Laura Koesten E-mail: laura.koesten@univie.ac.at Phone: +43-1-4277-79020

A. Appendix

Understanding Map Visualizations of Crisis Issues – Information for participants and declaration of consent

Project Leader	Name: Dr. Kathleen Gregory E-mail: kathleen.gregory@univie.ac.at Phone: +43-676-3434-592
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11. Declaration of consent

Name of the participant in block letters:

Date of birth:

I agree to participate in the study “Understanding Map Visualisations of Crisis Issues”.

Sandra-Maria Starchenko 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, especially section 4 (regarding risks, discomforts or side effects). The 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 Sandra-Maria Starchenko, either in writing or verbally.

At the same time, I agree that my data collected in this study are recorded and analysed. I agree that my data is saved electronically in pseudonymised form (through the allocation of an ID number, under which the data will be saved).. The data are saved in a form that is only accessible to the project management and are secured according to current standards. After the evaluation of the data the identification key of the assigned IDs is permanently deleted. The data is then permanently stored in anonymized form. If I want my data to be deleted at a later time, I can arrange for it by contacting Sandra-Maria Starchenko either in writing or via telephone (a11928744@unet.univie.ac.at , +43-681-20-86-23-19), and without having to give a reason. I have read and understood the information for participants. In the explanatory meeting, 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 declaration of consent. The original remains with the study coordinator.

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

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

A.5. Codebook comment study

The comments were transcribed and subsequently analyzed using Atlas.ti, a qualitative data analysis software. Codes were derived through a systematic review of the collected comments, identifying recurring themes and patterns. Axial coding was then applied to group the codes into themes that represented various thought processes. The codes were further categorized into three thought process activities: first impression, deeper engagement, and personal relation. A total of 45 codes emerged from the analysis, and a second round of analysis was conducted to ensure accurate categorization. Saturation of the data was achieved with a range of 20 to 25 comments per visualization, indicating that a comprehensive range of perspectives had been captured. It is worth noting that quantifying the results would be misleading since multiple individuals or even entire groups may have contributed to a single comment. The following tables A.6, A.7, and A.8 provide an overview of all codes used in the comment analysis. They are assigned to the respective themes and described in detail. Citations are provided for each code to improve understanding.

A.5. Codebook comment study

FIRST IMPRESSION		
CODE NAME	DESCRIPTION	EXAMPLE
color	Participants describe existing colors on the map, as for example, color hues, eye-catching color points etc.	<i>"There's not a lot of protected areas of biodiversity, a lot more red, significant amount of pink too." – VIS2</i>
introductory phrase	Participants use an introductory phrase before their analysis, by introducing the graph and its title.	<i>"I notice that the graph is telling about states where they think that the president should do more to support global warming." – VIS1</i>
challenge: probabilities/predictions	Participants have challenges with probabilities or future predictions on the map, because they think that the map depict real-planned or real-live scenarios	<i>"I notice how the United States is going to increase its wind and solar footprint by a lot by 2050." – VIS4</i>
challenge: opposed meaning of variable	Participants refer to the opposed meaning of the variable, if negativ growth of the variable is outlined (seen for divergent color maps).	<i>"From 1931-1960, the most dryland is shown on the map." – VIS5</i>
notice outliers	Participants notice outliers on the map.	<i>"1 thing I noticed was that Wyoming and North Dakota didn't think Congress should do more at all, but they were in the minority as they were the only 2 states out of 50 in the blue." – VIS1</i>
explain variable and its meaning	Participants think about the deeper meaning of the variable and it's exact definition.	<i>"in the lower part we find a map of the United States with orange and blue points that indicate the rise and fall of temperatures in various parts of the country." – VIS 3</i>
preconceived thoughts	Participants use their preconceived thoughts and mind patterns in order to make sense of map contents.	<i>"Why its taking so long to be eco friendly, and why some people still smoke, cuz A its bad for them and B it hurts the air." – VIS 8</i>
read out trends by comparing	They read out trends by comparing graphs, geographical directions or item values.	<i>"The map that has the most number of percentages per state is the first map of "congress should do more." – VIS1</i>
read out trends by distribution	They read out trends by focussing on the distribution of the map according to geographical directions or color distributions.	<i>"I noticed that nearly all of the outer regions of the U.S. are saying that Congress should do more about global warming, whereas the inner states/middle regions do not see global warming as a problem." –in VIS 1</i>
read out trends by grouping	They read out trends by grouping high or low attribute values, specific categories or they build categories from their own knowledge.	<i>"There are large green areas in Cali, Idaho, and Wyo. There is also very low concentration in the great plains." – VIS 2</i>

Figure A.6.: Codebook of the theme 'First Impression'

A. Appendix

DEEPER ENGAGEMENT		
CODE NAME	DESCRIPTION	EXAMPLE
challenges: completeness	According to the participant, the graph does not seem to be complete.	"Also notice that Hawaii and Alaska are not on this map of the United States." – VIS 8
challenges: drift off	The map evokes associations that have nothing to do with the subject of the map. Participants tend to drift off from the topic.	"Why its taking so long to be eco friendly, and why some people still smoke, cuz A its bad for them and B it hurts the air." – VIS 8
challenges: facts are not on the map	Participants infer facts that are not on the map.	"I notice how the United States is going to increase its wind and solar footprint by a lot by 2050." – VIS 4
challenges: where is the attribute?	Sometimes the representation of a certain attribute on the map is not accurate enough. Participants describe that the attribute is not visible.	"I notice that almost nowhere on the map has a rising sea level risk." – VIS 7
challenges: wonder about the data	Participants wonder about the background of depicted map data. It was not clear from the map how the data was calculated or collected.	"I wonder why they divide the 3 maps with Congress, President, and Governor?" – VIS 1
prior contextual knowledge: climate change	Participants share their knowledge about climate change.	"Especially in recent events, there has been more extreme weather, heat waves, rising sea levels, etc. We must be aware that climate change affects everyone. Our futures depend on what we do now to fight this climate crisis." – VIS 1
prior contextual knowledge: demographics	Participants share their knowledge about demographics.	"I notice that the areas that are densely populated (and in generally hotter areas) are at more risk of having imperiled biodiversity while areas that have little populations of people have an abundant amount of biodiversity." – VIS 2
prior contextual knowledge: economy	Participants share their knowledge about economy.	"How this relates to my community is that it could affect animals on farms that are a main source of food, same with crops that are very much needed for any towns economy and survival." – VIS 3
prior contextual knowledge: environmental conditions	Participants share their knowledge about environment.	"In the graphs, I think that precipitation increased more in the East rather than the West because of the colder, wetter weather that is more common on the East Coast." – VIS 5
prior contextual knowledge: human activity	Participants share their knowledge about human activity.	"One of first things I notice is how in more popular states, like California and Florida, the areas for more imperiled animals are higher, which could be due to people destroying their habitats. But the West is more green areas than other areas unlike the east side." – VIS 2
prior contextual knowledge: politics	Participants share their knowledge about politics.	"It seems that the more democratic states tend to want congress, president and their governor to do more, but for the most part most people want congress out of everyone to do the most." – VIS 1
causes of the crisis: wonder about differences (maps, attributes)	If there are several attribute or several maps the participant wonders about the difference between them.	"I wonder why we need a lot of wind and solar footprint at the right side of the map in the middle." – VIS 4
causes of the crisis: wonder about distribution	The participants wonder about the distribution of the attribute on the whole map	"I also wonder why the east and west coast believe that the president should do more compared to the midwest." – VIS 1
causes of the crisis: wonder about expressive values	Participants wonder about the causes of the most outstanding values in terms of clusters or map elements (state, country, directional values)	"I wonder why most of the heat records were made in Oregon and Washington State." – VIS 3
causes of the crisis: wonder about outliers	Participants wonder about the value of outliers.	"I also wonder why states like North Dakota and Wyoming were outliers in the first map titled: Congress should do more." – VIS 1
causes of the crisis: wonder about past values	Participants wonder how the crisis would have looked liked in the past compared to the situation today.	"I wonder why there has been such drastic change of weather. Like why did the weather not change little by little." – VIS 3
reconsider conclusions	Sometimes participants reconsider their conclusions because not all map elements meet the conditions of the participant's previous statement.	"Although New Hampshire has a smaller population, it has a relatively high death rate." – VIS 8
use color as a reference	Participants refer to map areas by outlining the color.	"I notice that there are many red areas that aren't being protected, especially on the west coast. Most areas needing protection are near the coasts too." – VIS 2

A.5. Codebook comment study

PERSONAL RELATION TO THE MAP		
CODE NAME	DESCRIPTION	EXAMPLE
"crisis does not involve me"	Participants don't feel personally addressed by the map.	"This really doesnt affect my community because theres rarely any change in California but it does need a little more solar and wind footprint beofre 2050." – VIS 4
"Get Active!"	Participants feel the urge to take action against the crisis.	"This relates to me and my community because we are very conscious of these things, and I will try to help as best as I can to prevent the dark red from going everywhere." – VIS 2
"I am concerned"	Participants feel concerned about information presented.	"I can relate to this because climate change is a huge issue and is affecting the US and the world. As a citizen of the United States climate change really affects me and I want someone to help!" – VIS 1
assessment of the situation	Participants assess the impact of the crisis as 'good' or 'bad'.	"The entirety of the eastern part of the United States is bad, not as bad as the west coast, but bad." – VIS 2
use of expressive language	Participants use expressive language (bold letters, slang, etc.) in order to explain their feelings and emotions.	"I also wonder WHY so much of the US has water stress." – VIS 9
opinion about the map	The participants explain what impression the map makes on them.	I want numbers on this graph. I want to know how much land we are devoting to this unreliable, expensive, dream. 4:63 ¶ 174 in VIS 4
opinion about the topic	Participants express their opinions on the subject.	We understand that politics are important when addressing this issue and voting matters. 1:46 ¶ 190 in VIS 1
crisis impacts my surroundings	Participants describe how the crisis affects them personally.	"I live in a state that wants more done so it might effect gas prices, etc. I also live on the coast so maybe I lose my house one day." – VIS 1
outline residence value	Participants mention the attribute expression of their residence.	"As a resident of California this graph tells me that my state has a broad opinion on who is responsible for the solution. This is interesting because it shows the diversity amongst my state." – VIS 1
classify results of own state vs. the rest	Participants rank their residence in comparison to other states' results.	"This isn't a big impact on me and my community because we are one of the lowest, I think one impact could be that we realize that we need to watch and be healthy about not polluting are states so we dint end up like one of the bigger states." – VIS 8
share own experiences	Participants share stories and experiences related to the topic.	"This relates to me and my community because it effected everyone around me not only everyone but a lot of things were damaged from the heat and i was worried about people who don't have the advantage of an AC or something to keep them cooled off." – VIS 3
purpose of the map	Participants outline the purpose of the map.	"I think this reflects on how our local policies impact our biodiversity and how we protect species that are endangered. Maybe it will encourage us to advocate for protection of local species that are facing threats." – VIS 2

Figure A.8.: Codebook of the theme 'Personal Relation'

A.6. Codebook interview study

As seen in the comment study, we also analyzed the interview transcripts using the qualitative data analysis software Atlas.ti. Codes were derived via a systematic review of the collected comments, identifying recurring themes and patterns. Axial coding was then applied to categorize the codes into themes that represented various thought processes. This time, the codes were classified into four thought process activities: visual impression (A.9), conceptual meaning (A.10; A.11), deeper engagement (A.12; A.13), and affective factors (A.14; A.14). This time, it was possible to quantify the results since each interview involved a single participant. Thus, columns 'VIS1,' 'VIS2,' and 'VIS3' indicate how many participants mentioned a specific code. The code represents the area mentioned within a particular theme. The expression is the manifestation of each code. For instance, the first table shows the code 'Map Readability' and different expressions of it, such as 'Bad resolution,' 'covered elements,' 'display too small,' and so on. For each of these expressions, it is indicated how many individuals mentioned them for each visualization. In a brief overview column, it is also apparent which code was mentioned most frequently. The first bar corresponds to VIS1, the second to VIS2, and the third to VIS3.

A.6. Codebook interview study

VISUAL IMPRESSION					
CODE	EXPRESSION	VIS1	VIS 2	VIS3	OVERVIEW
Visual Impression	quantitative overview	17	18	15	
Map readability	quantitative overview	5	7	0	
Map readability	"absolute vs. Percentual values"	3	1	0	
Map readability	"the need to zoom into the picture"	0	2	0	
Map readability	"covered elements"	3	2	0	
Map readability	"relate no-data fields to low intensitiy expression of the variable"	0	2	0	
Map readability	"visual elements too detailed"	0	1	0	
Map readability	"display too small (cellphone)"	1	1	0	
Overall impression	quantitative overview	6	5	4	
Overall impression: 'assess clarity'	quantitative overview	5	4	4	
Overall impression: assess clarity	"clearly arranged"	3	0	0	
Overall impression: assess clarity	"eye-catcher"	0	2	0	
Overall impression: assess clarity	"messy/complicated"	4	3	4	
Overall impression: derive associations	quantitative overview	1	2	0	
Overall impression: derive associations	"climate change"	0	2	0	
Overall impression: derive associations	"warning"	3	0	0	
Map elements	quantitative overview	17	17	15	
Map elements: Visual description	"color"	17	16	10	
Map elements: Visual description	"map sectioning"	2	0	11	
Map elements: Visual description	"map section"	15	17	11	
Map elements: Visual description	"legend"	4	11	12	
Map elements: Visual description	"no-data fields"	0	12	0	
Map elements: Visual description	"source"	0	2	0	
Map elements: Visual description	"symbol"	13	0	0	
Map elements: Visual description	"title"	11	12	12	
Map elements: Critique	quantitative overview	7	5	6	
Map Elements: Critique: negative	quantitative overview	2	3	0	
Map Elements: Critique: negative	"contrast of colors"	2	2	0	
Map Elements: Critique: negative	"map is distorted"	0	1	0	
Map Elements: Critique: positive	quantitative overview	1	1	3	
Map Elements: Critique: positive	"contrast of colors"	5	6	3	

Figure A.9.: Codebook of the theme 'Visual Impression'

A. Appendix

CONCEPTUAL MEANING					
CODE	EXPRESSION	VIS1	VIS 2	VIS3	OVERVIEW
Understanding Conceptual Meaning	quantitative overview	18	18	18	
typical means	quantitative overview	14	15	9	
typical means: relate concepts to meaning	"absolute vs. percentual values"	2	0	0	
typical means: relate concepts to meaning	"color concepts"	1	12	9	
typical means: relate concepts to meaning	"geolocation"	1	0	0	
typical means: relate concepts to meaning	"width of circles"	11	0	0	
typical means: relate concepts to meaning	"missing data fields"	0	9	0	
typical means: relate concepts to meaning	"textual elements"	3	1	0	
typical means: relate concepts to meaning	"titel"	0	0	2	
typical means: relate concepts to meaning	"circles which cover each other"	1	0	0	
classification	quantitative overview	14	15	7	
classification: assess map elements	quantitative overview	0	0	2	
classification: assess map elements	"priorization of map elements"	3	1	0	
classification: assess map elements	"caught attention at first sight"	0	0	0	
classification: assess map elements	"intensity of color size is perceived as more important"	1	0	0	
classification: prioritize map elements	prioritize map elements	2	1	0	
classification: typical use	quantitative overview	14	15	6	
classification: typical use	"the used concept is familiar"	6	5	4	
classification: typical use	"the used concept is easy to understand"	10	9	4	
classification: typical use of a 'typical concept'	quantitative overview	9	13	4	
classification: typical use of a 'typical concept'	"concept is associative"	4	4	1	
classification: typical use of a 'typical concept'	"circles"	4	0	0	
classification: typical use of a 'typical concept'	"color concept"	6	11	4	
classification: typical use of a 'typical concept'	"grey background"	1	0	0	
lacking conceptual meaning	quantitative overview	14	18	17	
lacking conceptual meaning	"could lead to missing / inconclusive derivations"	6	4	3	
lacking conceptual meaning	"I am not a VIS expert"	1	1	5	
lacking conceptual meaning	"lacking concepts harm understanding"	3	3	13	
lacking conceptual meaning	"make assumptions of lacking concepts"	3	10	5	
lacking conceptual meaning	"suggest different design"	5	4	4	
lacking conceptual meaning	"the need for further explanation"	5	2	6	
lacking conceptual meaning because of ambiguity	quantitative overview	11	18	14	
lacking conceptual meaning because of ambiguity	"absolut vs. proportional values"	5	0	1	

100 Figure A.10.: Codebook of the theme 'Conceptual Meaning' - Part 1/2

A.6. Codebook interview study

CONCEPTUAL MEANING					
CODE	EXPRESSION	VIS1	VIS 2	VIS3	GRAPH
lacking conceptual meaning because of ambiguity	"ambiguity of overlapping red circles"	8	0	0	
lacking conceptual meaning because the ambiguity of missing data fields	quantitative overview	0	15	0	
lacking conceptual meaning because of the ambiguity of missing data fields	"why is data missing?"	0	10	0	
lacking conceptual meaning because of the ambiguity of missing data fields	"relate 'no-data' to low intensity value expression"	0	3	0	
lacking conceptual meaning because of the ambiguity of missing data fields	"the data is not available"	0	12	0	
lacking conceptual meaning because of the ambiguity of the lack of labeling	quantitative overview	4	3	10	
lacking conceptual meaning because of the ambiguity of the lack of labeling	"classification sections of color key"	1	2	9	
lacking conceptual meaning because of the ambiguity of the lack of labeling	"inconsistency / no labeling"	2	1	1	
lacking conceptual meaning because of the ambiguity of the lack of labeling	"no concrete numbers shown"	1	1	2	
lacking conceptual meaning because of the ambiguity of the measured variable	quantitative overview	1	10	13	
lacking conceptual meaning because of the ambiguity of the measured variable	"opposed meaning of variable"	0	2	0	
lacking conceptual meaning because of the ambiguity of the measured variable	"unclear meaning/definition of the variable"	1	8	13	
lacking conceptual meaning because of disassociation	quantitative overview	4	7	6	
lacking conceptual meaning because of disassociation	"unnecessary exaggeration of results because of depicted map concepts"	1	0	0	
lacking conceptual meaning because of disassociation of color concepts	quantitative overview	0	7	4	
lacking conceptual meaning because of disassociation of color concepts	color classification problems	0	2	0	
lacking conceptual meaning because of disassociation of color concepts	color should have positive or negative association	0	1	2	
lacking conceptual meaning because of disassociation of color concepts	"symbiological meaning of color is not fitting the topic"	0	4	4	
lacking conceptual meaning because of disassociation of geographical elements	quantitative overview	0	0	2	
lacking conceptual meaning because of disassociation of geographical elements	"what does the map sectioning mean?"	0	0	2	
lacking conceptual meaning because of disassociation of symbolical elements	quantitative overview	3	0	0	
lacking conceptual meaning because of disassociation of symbolical elements	"legend does not explain all circle sizes"	2	0	0	
lacking conceptual meaning because of disassociation of symbolical elements	" meaning of "+" "	1	0	0	
lacking conceptual meaning because of disassociation of symbolical elements	"placement of symbols"	2	0	0	
lacking conceptual meaning because of lacking	quantitative overview	5	1	9	
lacking conceptual meaning because of lacking	unknown geographical excerpts	5	1	9	

Figure A.11.: Codebook of the theme 'Conceptual Meaning' - Part 2/2

A. Appendix

DEEPER ENGAGEMENT					
CODE	EXPRESSION	VIS1	VIS 2	VIS3	OVERVIEW
missing context: outline expectations towards maps	"übersichtlichkeit vs. Informationsfülle"	4	1	4	
prior Knowledge & personal connection	quantitative overview	13	17	14	
prior Knowledge & personal connection is given	quantitative overview	9	17	8	
prior Knowledge & personal connection is given	"confirm results on the map"	7	8	1	
prior Knowledge & personal connection is given	"contextualize information"	4	10	7	
prior Knowledge & personal connection is given	"critically contemplate"	2	8	3	
prior Knowledge & personal connection is given	"prior knowledge interferes with shown results"	0	6	2	
prior Knowledge & personal connection is given	"surprise"	1	13	3	
prior Knowledge & personal connection is lacking	quantitative overview	9	0	9	
prior Knowledge & personal connection is lacking	"could lead to misinterpretations"	2	0	0	
prior Knowledge & personal connection is lacking	"hard to understand the map"	0	0	4	
prior Knowledge & personal connection is lacking	"missing prior knowledge"	5	0	8	
prior Knowledge & personal connection is lacking	"no further conclusions possible"	1	0	1	
prior Knowledge & personal connection is lacking	"lacking"	4	0	1	
purpose of the map	quantitative overview	16	17	9	
purpose of the map: evokes preventive measures	quantitative overview	1	7	0	
purpose of the map: map design suits the purpose	quantitative overview	5	8	2	
purpose of the map: map usage	quantitative overview	2	4	1	
purpose of the map: map usage	"map can't be reused"	0	2	0	
purpose of the map: map usage	"use map as decision support"	2	2	1	
purpose of the map: types of messages	quantitative overview	15	17	8	
purpose of the map: types of messages	"comparative message"	1	1	0	
purpose of the map: types of messages	"geographical distribution"	11	7	6	
purpose of the map: types of messages	"negative"	0	2	2	
purpose of the map: types of messages	"raise awareness of the crisis topic"	2	13	1	
purpose of the map: types of messages	"retrospective message/future"	1	0	1	
purpose of the map: types of messages	"warning/gravity of the situation"	8	1	0	
purpose of the map: types of messages	"warning as message of the map"	4	2	0	
purpose of the map: types of messages	"conveyed through: messy impression"	1	0	0	
purpose of the map: warning as message of the map	"periodical comparison"	0	1	0	
purpose of the map: warning as message of the map	"conveyed through: signal colors"	3	2	0	
purpose of the map: warning as message of the map	"evokes reconsiderations of the message - possibly not a warning after all"	1	0	0	
purpose of the map: warning as message of the map	"was achieved"	3	10	2	

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A.6. Codebook interview study

DEEPER ENGAGEMENT					
CODE	EXPRESSION	VIS1	VIS 2	VIS3	OVERVIEW
deeper engagement	quantitative overview	18	18	18	
analysis	quantitative overview	16	17	13	
analysis: asking 'Why'	quantitative overview	2	4	4	
analysis: asking 'Why'	"internal reasoning"	1	3	4	
analysis: asking 'Why'	"questioning"	2	3	2	
analysis: finding meaning beyond the data	quantitative overview	5	6	5	
analysis: finding meaning beyond the data	"beyond the data"	5	5	5	
analysis: finding meaning beyond the data	"empathy"	1	3	1	
analysis: identify trends	quantitative overview	15	10	9	
analysis: identify trends	"derive causes of the crisis"	10	7	6	
analysis: identify trends	"derive impacts of the crisis"	1	0	3	
analysis: identify trends	"extract pattern and trends"	13	8	6	
analysis: spatial exploration	quantitative overview	7	13	5	
analysis: spatial exploration	"distribution"	7	12	5	
analysis: spatial exploration	"personal connection"	0	8	0	
missing context	quantitative overview	12	12	17	
missing context: demand more information	quantitative overview	0	3	8	
missing context: demand more information	"can't derive purpose of the map"	3	2	6	
missing context: demand more information	"demand more information"	9	8	10	
missing context: demand more information	"add additional diagram"	0	0	2	
missing context: demand more information	"add text"	1	2	6	
missing context: demand more information	"adding variables"	4	1	3	
missing context: demand more information	"outline causes/impacts of the crises"	3	2	2	
missing context: demand more information	"published data of the map"	1	2	1	
missing context: demand more information	"temporal development of the crisis"	1	2	1	
missing context: demand more information	"use additional information source"	1	2	1	
missing context: demand more information	"visualize europe"	1	0	1	
missing context: make assumptions without given context	quantitative overview	2	2	3	
missing context: map comprehension difficulties	quantitative overview	6	8	15	
missing context: outline expectations towards maps	quantitative overview	5	3	5	
missing context: outline expectations towards maps	"a map as standalone doesn't suffice in order to understand the whole topic"	1	1	0	
missing context: outline expectations towards maps	"a map should be fast comprehensive"	0	1	1	
missing context: outline expectations towards maps	"map visualizes quantitative data"	0	0	0	

Figure A.13.: Codebook of the theme 'Deeper Engagement' - Part 2/2

A. Appendix

AFFECTIVE FACTORS					
CODE	EXPRESSION	VIS1	VIS 2	VIS3	OVERVIEW
affective factors	quantitative overview	16	15	13	
motivation	quantitative overview	14	11	12	
motivation: map comprehension	quantitative overview	1	0	4	
motivation: map comprehension	"Maps must be easy to understand"	1	0	0	
motivation: map comprehension	"too hard to understand"	0	0	4	
motivation: relevance of the topic	quantitative overview	12	10	7	
motivation: relevance of the topic	"high - personal interest given"	2	6	3	
motivation: relevance of the topic	"high - personal interest given: das thema interessiert mich, ich möchte die grafik"	0	0	2	
motivation: personal interest given	"the topic is interesting, the country doesn't matter"	2	0	1	
motivation: personal interest given	"motivation to inform oneself further because the topic is relevant"	0	1	0	
motivation: personal interest given	"personal interest"	0	2	1	
motivation: personal interest given	"personally affected"	0	3	0	
motivation: recency of the topic	"be prepared for the future"	3	0	0	
motivation: recency of the topic	"be prepared for the future"	1	5	0	
motivation: recency of the topic	"overall relevance of the topic"	2	0	0	
motivation: recency of the topic	"low"	7	5	0	
motivation: recency of the topic	"low - crisis from the past: the crisis was over-communicated"	2	0	0	
motivation: recency of the topic	"low - crisis from the past: card/crisis is from the past"	6	0	0	
motivation: low - lack of personal interest	"could motivate other people which express their interest to the topic"	2	0	4	
motivation: low - lack of personal interest	"geolocation does not interest me"	1	0	0	
motivation: low - lack of personal interest	"more context to arouse interest"	0	0	2	
motivation: low - lack of personal interest	"I am not interested in the topic"	1	0	2	
motivation: visual appeal	quantitative overview	4	0	2	
motivation: visual appeal	"high - eye-catcher"	1	2	5	
motivation: visual appeal	"high - pleasant colors"	0	0	0	
motivation: visual appeal	"high - simple presentation"	1	0	2	
motivation: visual appeal	"low - chaotic impression"	2	1	0	
trust	quantitative overview	10	9	5	
trust: clarity	quantitative overview	2	8	1	
trust: clarity	"Usage of color red is confusing"	1	1	0	

Figure A.14.: Codebook of the theme 'Affective Factors' - Part 1/2

A.6. Codebook interview study

AFFECTIVE FACTORS					
CODE	EXPRESSION	VIS1	VIS 2	VIS3	OVERVIEW
trust: clarity	"I need more detailed data"	0	0	0	
trust: clarity	"More detailed legend leads to more trust"	1	0	1	
trust: ethical considerations	quantitative overview	1	5	0	
trust: ethical considerations	"unsettling the citizens with the publication of the map"	1	5	0	
trust: ethical considerations	"intentional omission of countries"	0	5	0	
trust: accuracy and reliability	quantitative overview	6	5	0	
trust: accuracy and reliability	"also check other sources for comparison"	0	5	0	
trust: accuracy and reliability => high	quantitative overview	4	1	0	
trust: accuracy and reliability => high	"missing data on the card means that the map designer is honest"	0	3	0	
trust: accuracy and reliability => high	"source is trustworthy"	4	2	0	
trust: accuracy and reliability => high	"important to check the source"	2	1	0	
trust: accuracy and reliability => low	quantitative overview	4	0	0	
trust: accuracy and reliability => low	"when was the data collected?"	0	1	0	
trust: accuracy and reliability => low	"Could be manipulated, need to double check with other sources"	1	1	0	
trust: accuracy and reliability => low	"No publication date"	1	0	0	
trust: accuracy and reliability => low	"crisis data could be manipulated"	1	0	0	
trust: accuracy and reliability => low	"more detailed source needed"	1	0	0	
trust: accuracy and reliability => low	"How was the dataset calculated?"	1	0	0	

Figure A.15.: Codebook of the theme 'Affective Factors' - Part 2/2