Unusual suspects - visualizing unusual relationships of complex social phenomena with climate change

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ABSTRACT

Information visualization is a powerful tool to communicate complex social/political/environmental phenomena. In spite of that, the complexity of these phenomena and the data involved can result in complex visualization or simplification of the visuals and a consequent data loss. To tackle this topic, we designed an interactive visualization to facilitate the understanding and awareness of the interdependencies and consequences of a complex social/political contemporary phenomenon, such as the war ravaging Ukraine. To this end, we engaged the public through a visualization that presents the interdependencies between the Ukrainian war and climate change in terms of environment, food and raw materials produced and exported, people (refugees and displaced), and support (military, humanitarian, and economic) provided to Ukraine. We evaluated our prototype and found that our visualization increased the users' awareness of war-affected aspects that directly or indirectly influence climate change, especially for food and people dimensions.

CCS CONCEPTS

• **Human-centered computing** → **Visualization systems and tools**; **Interactive systems and tools**.

KEYWORDS

design method; research through design; data visualization; climate change

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1 INTRODUCTION

Information visualization is a powerful tool to communicate complex social/political/environmental phenomena. As Tufte noted 40 years ago, "Graphic elegance is often found in the simplicity of design and complexity of data" [44]. Sometimes, the complexity of the phenomena and the data involved results in complex visualization or simplification of the visuals and consequent loss of data. The readers are then faced with either a simplistic vision of the complexity and interdependency of the phenomena, leading to misinformation due to an incomplete or inexact rendition of it, or excessive complexity of the visualization, leading to a lack of understanding or loss of engagement with the topic [29, 46]. However, today's progress in visual communication [15] and the spread of digital and interactive tools allow for visualization strategies that help to overcome a reader's difficulties. This research aims at experimenting with interactive information visualization tools and recent communication guidelines that advocate for the representation of complex data in a humanized yet complete way [25]. In order to tackle this topic, we decided to focus our experiment on a complex contemporary issue, such as the war ravaging Ukraine and affecting our society on a global scale. Similarly to the COVID-19 pandemic, the current war in Ukraine has important global consequences in terms of health, air pollution, the environment, food production, supply chains, and biodiversity, all dimensions influencing climate change. For instance, the impact of the COVID-19 pandemic on the global supply chain is still affecting many economic sectors like travel and semiconductors. Likewise, the effects of the Ukrainian war in Europe are impacting inflation, the economies of many countries, especially those dependent on Russian oil and gas, and the global supply of food, causing hunger and migrations in many areas of the globe. Our goal is to visualize complex phenomena such as the Ukraine war and engage the public through interactive visualizations, to facilitate the understanding and awareness of the interdependencies of these complex social/political phenomena. In order to investigate this topic, we designed a visualization of the Ukrainian war, guided by data humanism and recent trends in communication [15, 25]. Considering the various consequences of the Ukrainian war, in this study, we focused on the interdependencies between war and climate change. We present our prototype and its preliminary evaluation results in the following sections.

2 RELATED WORKS

2.1 Visualize war

War is often portrayed and explained through the use of visual communication, which is frequently associated with pictures and photographs (as in newspapers [34]), videos (as in news reports or online articles[1]), or maps. The use of visual elements depicting battles, military strategy, and people (both soldiers and casualties) usually evokes emotion and a connection to the issue and the people directly involved [12]. However, photographs or videos are not enough to show the full impact and complexities of war or situations involving large amounts of data. Analytical mapping tools deal with the intricacies of complex phenomena in greater depth. Harking back to the mid-19th century, innovations in both statistical graphics and thematic mapping flourished, and people "invented" many statistical graphics and thematic maps. Gilles Palsky (1996), Robinson (1982), and Friendly (2008) describe this burst of invention in detail [17, 35, 40]. Noteworthy diagrams inventions of the nineteenth century include William Playfair's time series line graph, the bar graph, the circle diagram pie chart, and Florence Nightengale's polar area diagram; maps include the choropleth map, dot map, flow map, and isoline map. Minard played an important role in stimulating the rise of visual thinking and explanation during this formative period. Nightingale's polar area visualization (1858) to illustrate the number and causes of deaths in the British army during the Crimean War (1854-1856) and Miniard's visualizations of Napoleon's disastrous invasion of Russia in 1812–1813 (1869) , respectively are still widely studied today marking the fundamentals of analytical design and mapping [5, 23].

As technology has advanced, data visualization and communication evolved accordingly. An example of this is presented in [26], where the authors used Minard's graph as a case study to investigate how Augmented Reality (AR) can be adapted to information design. In their study, they looked at three different experiences. In the first, Minard's map was augmented with a 3D model of the geographic terrain overlaying the original map; in the second, some points on the map related to specific events and battles were enriched with a new layer of information to make them easier to understand; and in the third, the map was augmented with materials such as photos, audio, video, and reports. However, they showed how the simultaneous interaction with both the mobile device and the virtual object distracted the user from the content [26]. Nevertheless, AR technologies are evolving as a supporting tool for information visualization ([37, 38]). A relevant example is the AR filter designed to be shared on social media, showing what a war in your own country would look like and, therefore, raising awareness about the Russian-Ukrainian war[2]. Another example is PalmitoAR, which aimed to divulge information related to the Battle of Palmito Ranch, to students and tourists. In particular, the authors used marker-based AR on a printed map [32]. Their study highlighted the general enthusiasm of the participants, but even in this case, the AR application posed certain problems, especially in relation to the 3D models. In particular, the 3D models did not seem realistic and caused some flickering problems. Moreover, there were issues on some devices as they do not support full-screen mode and had a misalignment with the textual description. Finally, users highlighted the fact that less information was displayed. Awareness of these problems has prompted us to consider other technologies for visualizing war.

In particular, the last few decades have seen a gradual shift from print to digital media and from charts printed on paper to interactive infographics or dashboards ([10, 20]). In [22], a visualization map of the battles of the Finnish Civil War was used as a case study for the development of interfaces for semantic portals based on Linked Data and exploiting a JavaScript framework. Moreover, the data was translated into an animation to display the advancement of battles in time. On the contrary, Poppy Field[3] is both an interactive web-based infographic and an installation in a permanent exhibition in Austria. This infographic was for the first time presented as a printed infographic in [11] and showed wars from 1899 to 2014 in the form of poppies as they are a well-known symbol of commemoration. Each poppy's stem started growing in the beginning year of the war, and the flower is situated in its last year. The poppy's size shows the number of casualties, and the variation of color represents the geographical areas involved. More recently, the Russo-Ukrainian war has been depicted in the major newspaper through the use of maps and charts (pictograms, bar charts, and line charts), although as static images or with a limited interactivity[4][5][6].

Building on and extending the variety of work and approaches, we focused our investigation on the design and early prototyping of an interactive web-based infographic representing the Ukraine War. The visualization would allow the users to directly interact with the represented data and gauge its complexity and spilling effects. To the best of our knowledge, we did not find an interactive visualization of the Ukraine war, or any study investigating the potential of interactive visualizations in its facilitating the understanding of the phenomena and raising awareness about its complex interdependencies, including its effects on Climate change.

2.2 The interdependencies of the spillover effects of the Ukrainian War

Russia's invasion of Ukraine has many devastating consequences. The most immediate is for the Ukrainian people and their well-being, including effects on their territory, infrastructures, and economy. But the war has wider global implications, and, looking at the long-term effects, the environment and climate are also at risk [28]. As Holden Thorp said, diplomacy is needed to improve the climate situation, and all nations should work together to reaffirm their commitment to the cause. Moreover, the link between conflicts and climate change is deeply investigated in literature to better understand if it can be considered unilateral or bidirectional [3, 41, 42].

As highlighted in [39], the Ukrainian war has an impact on several spheres of influence. These spheres include the economy (in terms of inflation and disruption of the supply and trade chain),

[1] https://www.nytimes.com/2022/12/22/video/russia-ukraine-bucha-massacre-takeaways.html
[2] https://arfected.com/ar-filter-war-ukraine/
[3] https://www.poppyfield.org/
[4] https://www.nytimes.com/interactive/2022/world/europe/ukraine-maps.html?smid=tw-nytimes&smtyp=cur
[5] https://www.nytimes.com/interactive/2022/02/15/business/energy-environment/russia-gas-europe-ukraine.html
[6] https://ig.ft.com/how-serious-is-putin-about-russia-invading-ukraine/

infrastructure (in terms of damage to roads, buildings, education system, and agro-ecosystem), health and wellness (in terms of the healthcare system, higher mortality, and mental issues), and environment (contamination of water and soil, air pollution and climate change). Concerning air pollution, the Ukrainian areas affected by the war were also the ones with higher PM 2.5 concentrations even before the war. As a matter of fact, the average concentration of PM 2.5 overcame the limits imposed by the World Health Organization (WHO) in the regions of Donetsk and Dnipropetrovsk, and in Kyiv [4].

The effects on the environment are also investigated by Pereira et al. in [36], where they identified four macro areas impacted by the war: i) air quality and greenhouses gases emission, ii) biodiversity, iii) soil and landscape morphology, and iv) water availability and quality. The negative impact of the war on these four areas is tied to a repercussion on three ecosystem services impacted: regulating, provisioning, and cultural. Moreover, as mentioned in [2], global food security is one of the main consequences of the Ukrainian war. As a matter of fact, war will worsen a situation already made critical by the COVID-19 pandemic, especially for countries in the Middle East and North Africa that depend on food imports. The war may also threaten the accomplishment of some Sustainable Development Goals, like no poverty, zero hunger, and responsible consumption and production [2]. Also, the United Nations acknowledged the global impact of the war on food, energy, and finance [31].

Based on the numerous side-effects of the Ukrainian war, we designed a visualization that wants to highlight their complex interdependencies. While usually when talking about war, only one type of information is privileged, namely casualties, we decided to illustrate five interrelated topics that influence climate change. The first four are: food, people, war support, and raw materials, based on the information that we were able to collect. We arranged these topics around the central fulcrum of the environment (our fifth dimension), being the most pressing and discussed challenge of this millennium.

3 METHODOLOGY

To understand: *how does visualizing complex phenomena (as the effects of the Ukrainian War) influence the way people understand and become aware of the consequences*, we adopted a research-through-design approach [47] and proceeded with the ideation and design of such visualization. In this first study, we focused on the consequences related to climate change.

First, we started collecting data for the visualization focusing on a set of dimensions of the war, that seemed deeply interconnected. The interconnection between climate change and the Ukraine war was highlighted in several articles from major national and international newspapers, for example, [33] which highlighted the interconnected positive and the negative effects of the war. In light of this article, we started looking at the major causes of climate change as reported by the United Nations and European Commission in [6, 30]. We then extrapolated four main dimensions that are a risk for the climate and, at the same time, are influenced by the war: *food*, *raw material*, *people*, and *war support* (as they are delivered using means of transport). The production of food causes the emission of greenhouse gases in several ways, from deforestation, for the creation of cultivable space for agriculture, to fertilizers, exploited to speed up the growth of the crop [30]. We included raw materials (oil, gas, and others like neon) as they are commonly used in several manufacturing and industry processes for the production of goods and electricity and because the manufacturing industry is one of the main perpetrators of greenhouse gas emissions [30]. Concerning the people dimension, the migration flows of refugees and displaced people can harm the environment and climate change as a consequence. The displaced people's settlements and the refugee camps can worsen the degradation, especially in poor areas where resources (like water or food) are already limited [13, 16]. We also included war support (medical aid and weapons) as most support is directly transported to Ukraine. Means of transport like trucks or, more in general, road vehicles cause greenhouse gas emissions, due to the combustion of petroleum-based products. Also, ships and planes are not exempt from the release of emissions [30].

Moreover, analyzing the current literature, we decided to include *environment* as a fifth dimension ([36, 39]). As a matter of fact, the war in Ukraine has caused the increment of warming gases released into the atmosphere, the risk for biodiversity, and the destruction of land due to bombing and landmines [1, 6].

The fluid interconnection of the elements we decided to visualize called for the metaphor of an assemblage as a central tenet for the functioning of a complex agglomerate of different elements. Assemblage theory is a posthumanist philosophical approach that redistributes the capacity to act from an individual to a socio-material network of people, things, and narratives ([27]). There are multiple philosophical approaches that use an assemblage perspective. One version is associated with Manuel DeLanda in his work on assemblage theory ([8]); a second version is associated with Bruno Latour and Michel Callon on Actor-network theory ([24]). A third version draws from Gilles Deleuze and Félix Guattari ([9]). They all refer to a relational view of social reality in which human action results from shifting interdependencies between material, narrative, social, and geographic elements ([8, 9, 24]). Deleuze and Guattari, DeLanda suggest that the social does not lose its reality, nor its materiality, through its complexity. In this way, assemblages are effective in their practicality; assemblages, though fluid, are nevertheless part of historically significant processes. From these definitions, we envisioned the data and its interconnections being represented through liquid qualities of the assemblage, shape-shifting, and forming reforming connections, as their materialities change and evolve.

We describe the design of our system in detail below.

4 INTERFACE DESIGN

The visualization of the war as an assemblage took several iterations, where the authors discussed, sketched, and refined its design over three prototypes, from low to high fidelity, as shown in Figure 1A, B, C. Each one of the five dimensions of the visualization (environment, people, food, raw materials, and war supplies), contain several sub-elements, each one represented by an icon. For each sub-element, data was collected and displayed on the side of the assemblage itself.

The final design takes the shape of an interactive representation of the complex phenomena of the Ukrainian war and its effects that have an indirect impact on climate change. To make the connection

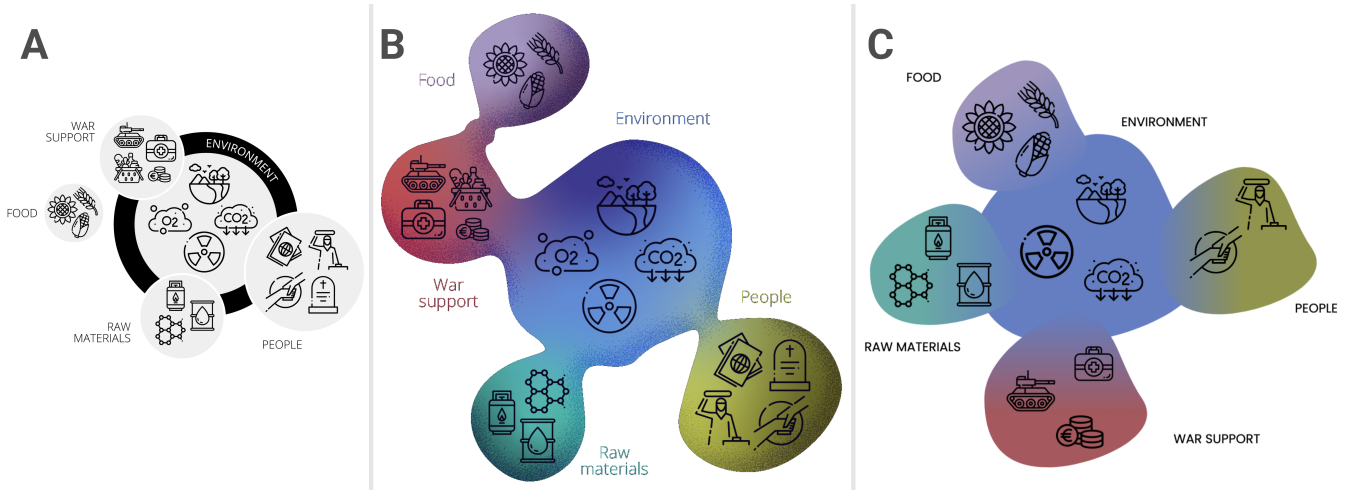

Figure 1: A. shows the low-fidelity wireframe, designed after the first brainstorming session, B. shows the mid-fidelity wireframe, designed after a first refinement, and C shows the final version of the assemblage.

between the different elements more explicit, we settled for the *storytelling* version of our system, visible in Figure 2. In particular, we enriched the assemblage visualization with short text-based paragraphs of explanation. The idea was to disentangle, step by step, the assemblage by explaining each dimension and sub-dimension and their relation to climate change, also providing meaningful numerical data.

As shown in Figure 2, the first interface of our prototype is an explanatory layer, where we briefly introduce the project and our intentions of explaining the connection between the Ukrainian War and Climate Change through the interactive visualization. Then, with one click on the button (C1 in Figure 2), the disentanglement begins bringing out the five dimensions we identified (second image in Figure 2). For each of the dimensions, there is a description concerning the dimensions and how they are related to climate change positively or negatively (third image in Figure 2). The final interface adds an interactive layer, as users can directly interact (fourth image in Figure 2). By clicking on each one of the icons inside the assemblage (C2 in Figure 2), more detailed data about each sub-dimensions is presented to the user. The type of data is strictly related to the sub-dimensions. Adding more details, we displayed historical data about the export of food and raw materials from Russia and Ukraine to highlight how the other states are dependent on Russia and/or Ukraine and how the situation could change due to the war. The data we exploited came from the UN Comtrade Database[7]. Concerning the war support dimension, we exploited the information provided by the Ukraine Support Tracker[8], and we showed the geographical information on the states which promised humanitarian, military, or economic support to Ukraine with the related quantity. For the people dimensions, we gathered and showed the number of displaced from a report made by the Organization for Migration during January 2023[9]. For the refugees, we gathered the data from the Operational Data Portal[10] made by the United Nations High Commissioner for Refugees and we showed the flows of refugees from Ukraine to other states. Finally, the numeric data about pollution and biodiversity came from a paper about the impact of the Russian-Ukrainian war on the environment [36], while data about the nuclear risks came from the Conflict and Environment Observatory (CEOBS)[11]. Concerning the map visualizations, they all are interactive, and with a hover on the marker (the blue circle in the fourth image in Figure 2), the users are able to see the related quantity of the export, the supports provided, or the number of the refugees in that state.

To develop the final version, we exploited standard web technologies (HTML, CSS, JavaScript) together with libraries for data visualization like D3.js[12] and for map visualization like Leaflet[13].

5 USER STUDY

To evaluate the capability of our prototype to raise awareness about the impact that the Ukrainian War on climate change, we recruited 15 users and engaged them in a three-step procedure, lasting 20 minutes. We asked them to complete a first questionnaire about their perception of climate change, war, and the interconnection between those two concepts, interact with the prototype, and complete a second questionnaire, similar to the first one, to investigate a change in their perception. Demographics were asked at the end of the study. To match the answers from the two questionnaires we asked the users to create a Self-Generated Identification Code (SGIC) (Q61 in Figure 3) based on: the first letter of their mother's name, the number of brothers they have (0 if none), the first letter of their father's name, the number of sisters they have (0 if none), and the number of the month in which they were born (1 to 12).

[7]https://comtradeplus.un.org/
[8]https://www.ifw-kiel.de/topics/war-against-ukraine/ukraine-support-tracker/
[9]https://dtm.iom.int/reports/ukraine-internal-displacement-report-general-population-survey-round-12-16-23-january-2023
[10]https://data.unhcr.org/en/situations/ukraine
[11]https://ceobs.org/ukraine-invasion-environmental-brief-nuclear-and-radiation-risks/
[12]https://d3js.org/
[13]https://leafletjs.com/

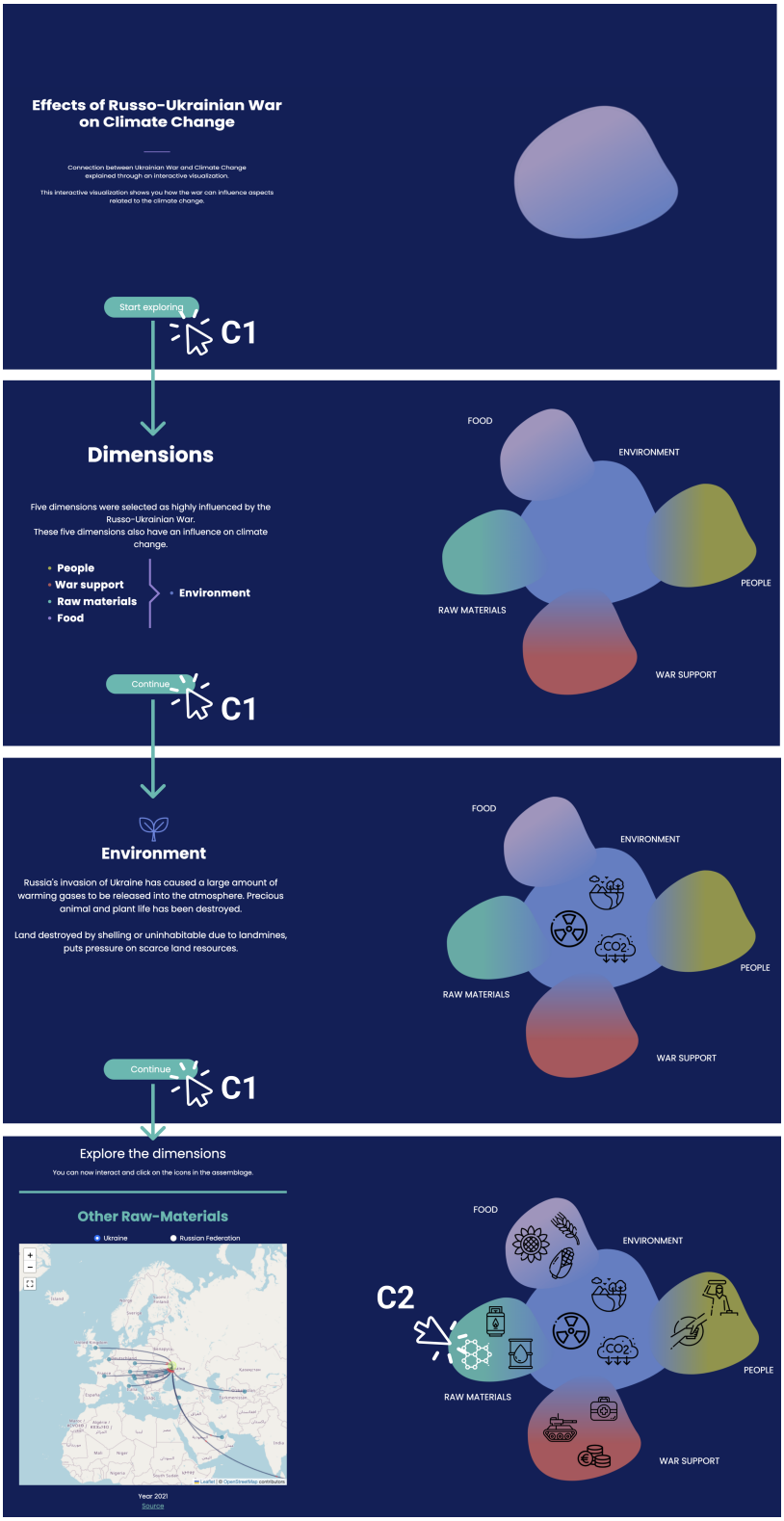

Figure 2: The final design of the system. The interface has a vertical layout and with each click on the button (C1), the user is able to discover more about the relationship between climate change and each dimension affected by the war. Finally, with a click on the icons inside the assemblage (C2), the user is able to see the data about historical data on the export of goods by Russia and Ukraine to have an insight into the states involved and how the situation could change with the current war.

Step 1: Pre-questionnaire. The first administered questionnaire was divided into three sections, each of them with a specific aim. The first one (Q1-Q15 in Figure 3) was related to understanding the users' perception of climate change and, to do so, we extrapolated 15 questions from the climate change perceptions scale, which was originally made of 25 items divided into 5 categories (reality, causes, valence of consequences, spatial distance, and temporal distance) [45]. Each item was evaluated through a 7-point Likert scale from 'strongly disagree' (1) to 'strongly agree' (7). The second section (Q16-Q24 in Figure 3) wanted to give us some insights into the users' perception of the Russian-Ukrainian War. We exploited some questions (5-point Likert scale) used in a global survey made by the Faculty of Public Administration, University of Ljubljana from Slovenia, in collaboration with international academic partners [14]. Finally, the last section (Q25-Q39 in Figure 3) was strictly related to our study as we asked to what extent each of our 15 sub-dimensions impacts climate change. Through a Likert Scale from 1 (Not at all) to 5 (Extremely) we asked the users' opinions on nuclear risk, loss of biodiversity, pollution, the production and the export of sunflower seeds, wheat, corn, gas, oil, other raw material (e.g., neon), refugees, displaced, and weapons, medical aids, and money provided. After testing the questionnaire we also added the option "I don't know" to improve the quality of the answers. In this section, we also included an open question asking users if they saw some other dimensions influenced by the war that have an impact on climate change that we did not mention.

Step 2: Interaction with the prototype. The second step of the evaluation is the interaction with our prototype. We asked the users to go through the entire visualization to learn about the assemblage and the dimensions (and sub-dimensions) of which it is made of. This step includes the interaction with the historical data that showed the situation before the war to give an idea of how the import/export of goods and material could change.

Step 3: Post-questionnaire. For the second questionnaire, we kept the same sections mentioned in Step 1, but we added a fourth section about the demographics. Adding more details, for the section on climate change perception (Q4-Q6 in Figure 3), we kept only the 3 questions on the causes category. For the perception of the war section, we kept only a question (Q16 in Figure 3) to see if the visualization had made some changes in the users' concerns about the war. Finally, we kept all the questions of the section on the users' perception of climate change and war (Q25-Q39 in Figure 3). For the demographics section, we asked for gender (Q40 in Figure 3), age (Q41 in Figure 3), a test question to monitor the users' attention in answering the questionnaire (Q42 in Figure 3), the country where the users currently live (Q53 in Figure 3), and where they were born (Q54 in Figure 3). In this section (Q43-Q52 in Figure 3), we also exploited the Ten Item Personality Measure (TIPI) ([19]) to understand if there is a relation between the answers on perception and the personality of the users, as mentioned in [21].

Metric. We computed the change in the users' perception (Δ) before and after the interaction with our visualization exploiting the questions asked both in the pre and post-questionnaire. In particular, we calculated Δ as the score from the post-questionnaire minus the score from the pre-questionnaire. Adding more details, a Δ smaller than zero indicates a lower scoring response (closer to "strongly disagree"), a Δ equal to zero indicates the same answers before and after the interaction, and a Δ higher than zero indicates a response closer to "strongly agree" after the interaction.

5.1 Results

We engaged 15 users for our evaluation. However, we remove one user based on the test question (Q42). So, our final user sample was composed of 14 users, 11 males and 3 females, aged between 18 and 34. Concerning their personality, based on [18], they scored low for extraversion ($\mu = 3,1$ and $\sigma = 1,3$), agreeableness ($\mu = 4,3$ and $\sigma = 0,9$), and openness to experiences ($\mu = 4,8$ and $\sigma = 0,8$), medium in emotional stability ($\mu = 4,5$ and $\sigma = 1,2$) and high in conscientiousness ($\mu = 5,0$ and $\sigma = 1,3$). All the users were born in Italy and all of them are living in Italy, except one who is currently in Estonia.

Climate Change Perception (Q1-Q15). All participants believed that climate change is real and is occurring. That is proven by the answers from Q1 to Q3, visible in Figure 4. Regarding the causes, all users were aware of human participation in climate change as all of them answered "strongly agree" and "agree" to Q4. Proof of this is the responses to Q5 and Q6, visible in Figure 4. The participants were also aware, at different levels, that climate change will bring negative and serious consequences, as visible in the answers from Q7 to Q9 in Figure 4. Regarding the spatial distance of climate change, analyzed in Q10 to Q12, the participants were, in general, aware that their local area will suffer the consequences of climate change, as visible in the answers in Figure 4. Finally, the participants believed that the consequences are already visible and not only the future generation will see them. This is confirmed by the answer from Q13 to Q15, visible in Figure 4.

After the interaction with our prototype, the participants were more aware that humans have an effect on climate change. This is proven by the Δ calculated on Q4, Q5, and Q6 and visible in Figure 5. Analyzing, Q4, the perception that human activities are a major cause of climate change is increased in 6 participants ($\Delta > 0$), a number very relevant as already 6 of them answered "strongly agree" in the pre-questionnaire and kept the same answer in the post-questionnaire, so they could not improve their answer. In confirmation of this, the answers to Q5 and Q6 indicate a decrease in the perception that natural processes are the main causes of climate change. As proof of this, 6 participants had a $\Delta < 0$ for Q5 and 4 for Q6.

War perception (Q16-Q24). In general, our participants were worried about the Ukrainian war, as proven by Q16, a Likert Scale from "not at all" (1) to "extremely" (5) ($\mu = 3,6$ and $\sigma = 0,8$). This is justified by the fact that the majority of them (71%) actively look for information often or sometimes (Q17). The concern increased for 3 participants after the interaction with the visualization, as shown in the Δ in Figure 5. Also, the prices of goods and services during the war generated concern as proven by the 5-point Likert scale questions from Q18 to Q24. In particular, our participants were worried about the prices of energy ($\mu = 4,4$ and $\sigma = 0,9$), and essential goods ($\mu = 3,8$ and $\sigma = 1,3$), higher inflation ($\mu = 4,0$ and $\sigma = 1,1$), higher taxes ($\mu = 3,7$ and $\sigma = 1,2$), supply-chain problems

ID	Question		Section
Q1	Rate the following statements	I believe that climate change is real	Climate Change Perception
Q2		Climate change is NOT occurring	
Q3		The world's climate is changing	
Q4		Human activities are a major cause of climate change	
Q5		Climate change is mainly due to natural causes	
Q6		Climate change is caused entirely by natural processes	
Q7		Overall, climate change will bring more negative than positive consequences to the world	
Q8		Climate change will mostly have positive consequences	
Q9		The consequences of climate change will be very serious	
Q10		My local area will be influenced by climate change	
Q11		Climate change only influences locations far away from me	
Q12		The region where I live will experience the consequences of climate change	
Q13		The consequences of climate change are visible now	
Q14		It will be a long time before the consequences of climate change are felt	
Q15		Only future generations will experience the consequences of climate change	
Q16	To what extent do you worry about the Russia-Ukraine war 2022?		War Perception
Q17	How often do you actively look for information about the Russia-Ukraine war 2022?		
Q18	To what extent do you worry about the prices of goods and services during the Russia-Ukraine war?	Higher energy prices (oil, gasoline, gas, electricity, etc.)	
Q19		Higher prices of essential goods (food, clothing, housing, etc.)	
Q20		Higher prices of luxury goods (computers, smartphones, tablets, etc.)	
Q21		Higher inflation	
Q22		Higher taxes	
Q23		Supply-chain problems	
Q24		Increasing poverty	

ID	Question		Section
Q25	To what extent do you think the following categories impact climate change?	Nuclear Risk	Climate Change and War Perception
Q26		Loss of biodiversity	
Q27		Pollution	
Q28		Sunflower Seeds - production and import/export	
Q29		Wheat - production and import/export	
Q30		Corn - production and import/export	
Q31		Refugees	
Q32		Displaced	
Q33		Oil - production and import/export	
Q34		Gas - production and import/export	
Q35		Other raw material (e.g., neon) - production and import/export	
Q36		Weapons provided	
Q37		Medical ids provided	
Q38		Money provided	
Q39	Do you think that there are some other dimensions/category influenced by the war that have an impact on climate change?		
Q40	To which gender identity do you most identify?		Demographics
Q41	What is your age?		
Q42	Without speculating on possible advances in science, how		
Q43 - Q52	Ten Item Personality Measure (TIPI)		
Q53	In which country do you currently live?		
Q54	In which country were you born?		
Q55	Please share any comment or suggestion on the project.		
Q56	Self-Generated Identification Code (SGIC)		

Figure 3: Set of questions asked in the two questionnaires. The questions in white are the ones asked only during step 1 (pre-questionnaire), the questions in yellow are the ones asked only in step 3 (post-questionnaire), while the ones in light blue are asked both in step 1 and step 3 to evaluate the possibility of a shift in the users' perception.

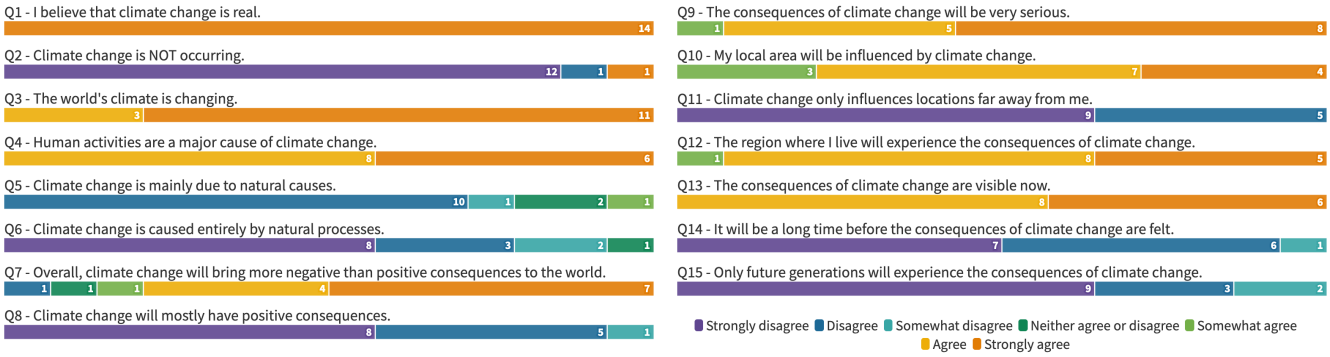

Figure 4: The climate change perception of our participants.

($\mu = 3,8$ and $\sigma = 1,1$), and the increase in poverty ($\mu = 3,7$ and $\sigma = 1,0$). However, in general, they do not recognize a problem with the prices of luxury goods ($\mu = 3$ and $\sigma = 1,7$).

Climate change and war perception (Q25-Q38). The participants' perception of the influence of the war sub-dimensions on climate change can be seen in Figure 6. In particular, they evaluated a low impact of refugees ($\mu = 2,7$ and $\sigma = 1,3$), displaced ($\mu = 2,4$ and $\sigma = 0,9$), and medical aids provided ($\mu = 2,9$ and $\sigma = 1,5$), medium the impact of money provided ($\mu = 3,2$ and $\sigma = 1,5$). On the contrary, they had a high score for nuclear risk ($\mu = 3,7$ and $\sigma = 1,4$), loss of biodiversity ($\mu = 3,7$ and $\sigma = 1,3$), pollution ($\mu = 4,4$ and $\sigma = 0,6$), production and import/export of sunflower seeds ($\mu = 3,4$ and $\sigma = 0,9$), wheat ($\mu = 3,8$ and $\sigma = 1,1$), corn ($\mu = 3,4$ and $\sigma = 0,8$), gas ($\mu = 4,1$ and $\sigma = 0,9$), oil ($\mu = 3,9$ and $\sigma = 0,9$), and other raw materials ($\mu = 3,3$ and $\sigma = 0,9$) and weapons provided ($\mu = 3,4$ and $\sigma = 1,3$). Based on these answers, we computed the Kendall rank correlation between the answers to Q25-Q38 in the pre-questionnaire and the personality traits. We noticed a medium negative correlation between the importance given to nuclear risk (Q25 of the pre-questionnaire) and the agreeableness

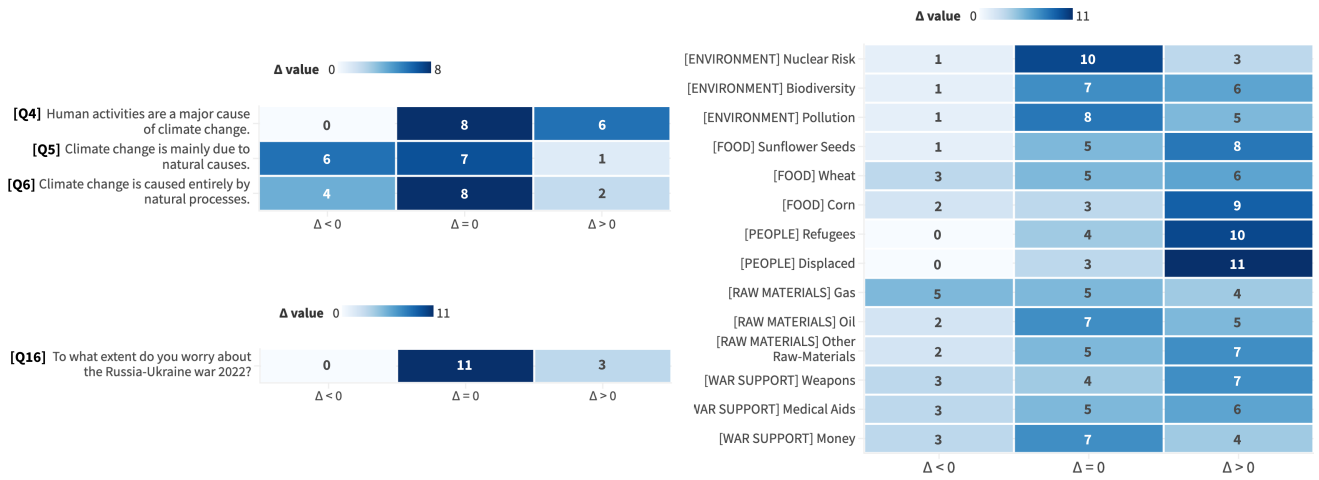

Figure 5: The Δ computed for climate change perception (top-left heatmap), for the level of concern about the Ukrainian war (bottom-left heatmap), and for the perception of the impact of the sub-dimensions we selected in relation to climate change (right heatmap).

traits ($\tau = -0,46$ and $\rho = 0.04$), and a strong negative correlation between consciousness traits and gas ($\tau = -0,52$ and $\rho = 0.03$), and openness to experience and displaced ($\tau = -0,57$ and $\rho = 0.02$). After the interaction with the visualization, the participants, in general, kept the same response or increased the importance of the sub-dimension with regard to climate change, especially for the people dimension (displaced and refugees), as shown in Figure 5. On the contrary, the importance given to gas decreased for 36% of the participants. All the answers are visible in the box plot in Figure 6. We also computed the Kendall rank correlation between the Δ for each dimension and the personality traits and found that there is a positive correlation between consciousness and refugees ($\tau = 0,48$ and $\rho = 0.04$).

Qualitative feedback. From the open questions (Q39 and Q55), we gathered some feedback on the visualization. In particular, regarding the dimensions influenced by the war and impacting climate change, P4 mentioned that "Facilities are no longer properly working in terms of recycling and trash/war material disposal". P1 highlighted a "Lowered interest of the general public in climate change due to the shifting of attention.". Finally, the project generated some positive feedback. P9 stated: "Very interesting project, I really like website colors and the graphic to represent 5 factors that influence climate change.", this is very interesting as the participant also remembered the number of dimensions we considered; P14 also added: "really useful to raise the awareness of those who don't get informed", highlighting the capability of the visualization to raise awareness.

6 DISCUSSION

Climate change and the Ukrainian war are currently among the most discussed topics in the public domain and in the news. However, little is said about the interconnection between these two complex phenomena. This work revolves around the following research question: *how does visualizing complex phenomena (as the effects of the Ukrainian War) influence the way people understand and become aware of the consequences?*. Exploiting a research-through-design approach, we designed a visualization in the form of an interactive assemblage. Interactivity plays the role of engaging users and at the same time disclosing the complexity of the phenomena one step at a time. The results from our 14 users interacting with the visualization showed that the participants were, in general, affected by the visualization and enriched their perspectives through the understanding of the connection between climate change causes, war, and the way these two phenomena influence each other. In particular, after the interaction with our prototype, we noticed:

- an increased awareness for 43% of our participants of the fact that climate change is also linked to human activities, and not only to natural processes;
- an increase in the concern of war for some participants (21%), in relation to the explanation of all the consequences it can bring also in the long period;
- an increased awareness of war-affected aspects that have a direct or indirect influence on climate change, especially the ones related to people (refugees - for 71% of the participants, and displaced - for 79% of the participants) and food (corn - for 64% of the participants, and sunflower seeds for 57% of the participants).

The storytelling approach with vertical scrolling is often used in Data Journalism (e.g., [43]) to narrate events in a visual and interactive manner. Indeed, this approach has proven to positively influence our users, not only by conveying a timeline for the narrative but also by explaining the consequences and interdependencies of these complex events. The assemblage visualization was helpful as well in conveying the intricacies and non-linearity of the consequences and interconnection between dimensions, allowing users to remember the number of the dimensions involved in the interdependencies as proven by one of the qualitative feedback.

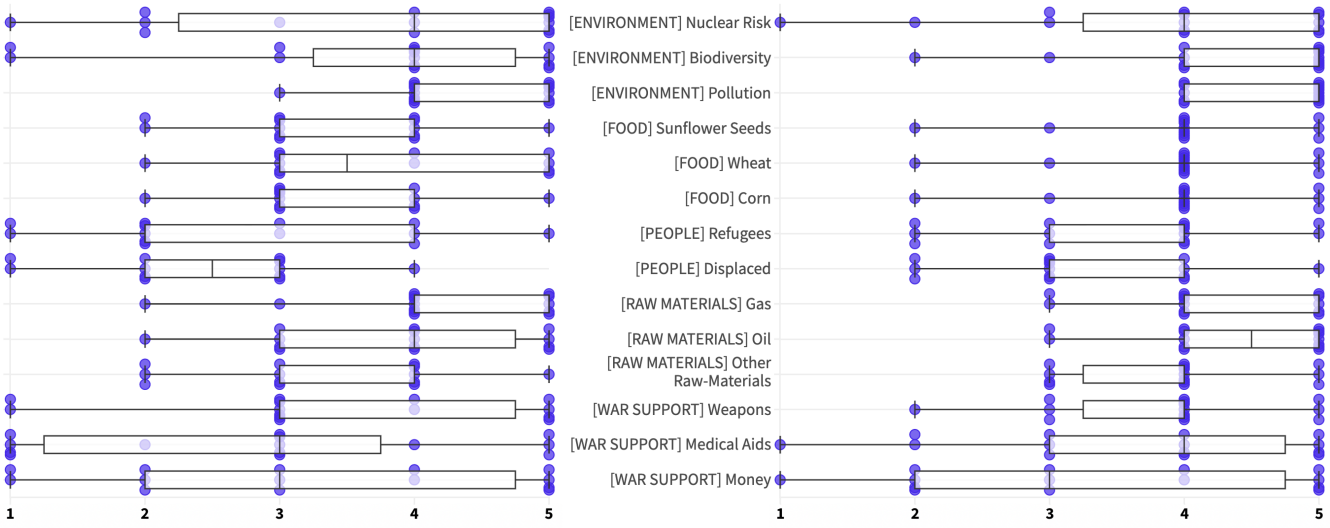

Figure 6: Breakdown of the answers to Q25 to Q38 in the pre- (on the left) and post-questionnaire (on the right). The answers were Likert scale from 1 (not at all) to 5 (extremely).

7 CONCLUSION, LIMITATIONS AND FUTURE WORK

In this study, we were not interested in communicating if the impact of the war on climate change is generally more positive or negative. Rather, we wanted to highlight that a relationship between those two phenomena exists and that war directly or indirectly impacts climate change. This is a preliminary work aimed at understanding if visualizations of this type can foster awareness. In particular, the goal is twofold: i) shedding light on the causes of climate change, and ii) raising awareness of the lesser-known effects of war, which are visible in the long term. Our preliminary work comes with two main shortcomings. First, our user sample was limited, but, at the same time, it showed a general positive interest in the project and some first positive results, which motivated us to take the project a step further. Second, our participants were all of Italian nationality, and there could be some differences in the way different nationalities perceive the war and the consequences based on their closeness to the war borders and resource dependencies on Russia or Ukraine. Regarding future work, we plan to refine the data story behind the Ukraine war and its effects on climate change, highlighting the data engagement and its connections. By refining the story, we plan to humanize the data and the data visualizations. Data humanism is a data visualization approach proposed by the information designer Giorgia Lupi that proposes to make data visualizations more approachable and relatable by connecting "numbers to what they really stand for: knowledge, behaviors, people" [25]. By linking complex data to personal stories or metrics, behaviors, and routines, we hope to assist in a better relation with global, complex, and oftentimes invisible data – such as climate change data – to assist in the journey from matters of concern to matters of care [7] and, ultimately, create more productive and action-focused dialogues about climate change. We are planning to evaluate the visualization in various countries with different degrees of proximity to the conflict and dependence on Russian or Ukrainian resources to investigate the possibility of perceiving the data and the visualization differently, also analyzing the education status of the participants and their digital literacy level.

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