Attitudinal Effects of Data Visualizations and Illustrations in Data Stories

Manuela Garretón, Francesca Morini, Pablo Celhay, Marian Dörk, and Denis Parra

***Abstract*—Journalism has become more data-driven and inherently visual in recent years. Photographs, illustrations, infographics, data visualizations, and general images help convey complex topics to a wide audience. The way that visual artifacts influence how readers form an opinion beyond the text is an important issue to research, but there are few works about this topic. In this context, we research the persuasive, emotional and memorable dimensions of data visualizations and illustrations in journalistic storytelling for long-form articles. We conducted a user study and compared the effects which data visualizations and illustrations have on changing attitude towards a presented topic. While visual representations are usually studied along one dimension, in this experimental study, we explore the effects on readers' attitudes along three: persuasion, emotion, and information retention. By comparing different versions of the same article, we observe how attitudes differ based on the visual stimuli present, and how they are perceived when combined. Results indicate that the narrative using only data visualization elicits a stronger emotional impact than illustration-only visual support, as well as a significant change in the initial attitude about the topic. Our findings contribute to a growing body of literature on how visual artifacts may be used to inform and influence public opinion and debate. We present ideas for future work to generalize the results beyond the domain studied, the water crisis.**

***Index Terms*—Attitude change, data stories, emotions, quantitative and qualitative evaluation.**

I. Introduction

JOURNALISM is experiencing profound transformations that are related to a range of socio-technological developments. In particular, the maturation of the web fundamentally changed the ways in which content is created, distributed, and consumed. At first, traditional news media responded reluctantly [1], but over the last decade online newsrooms have experimented with more innovative forms of storytelling. Some of these innovations involve integrating various visual elements into interactive article formats, including data visualizations, [2], [3], [4], [5], [6]. Visual representations embedded into online articles are often used to help convey complex issues of public concern, and therefore influence the way readers form an opinion about it. In recent years, interest in visualization as part of data stories has grown beyond academic visualization research into professional fields such as data journalism [4], [7]. While there are a range of assumptions at play about the rhetorical power of visualizations and illustrations in data stories, so far there is limited empirical evidence about their attitudinal effects.

In a data journalism context, data visualization usually operates in a space with different forms of visual representation such as illustration, photography, and videos. We are especially interested in understanding illustration in this study, since we see it as part of many related topics that have been studied within the data visualization research community; efficacy of embellishments [8], [9], infographics [10], anthropographics [11], and data comics [12]. Data visualization and illustration have been studied within these in an integrated way, and as such have been understood as communicative visualization techniques that are typically coupled. For example, the appropriate integration of visual embellishment in data representation may help viewers grasp key concepts more effectively [9]. In contrast, in our study we try to separate the effect of data visualization from illustration, trying to compare how these distinct visual representations operate individually and in combination with each other within an article. We are interested to find out how readers respond to these two related types of visual representations in the context of a particular story pertaining to a current issue of public concern. In short, we ask: How do the attitudinal effects of data visualization, illustration, and their combination in data stories compare?

The effect of visual representations embedded in journalistic articles has been addressed mainly by research in journalism and framing studies, where the notion of visual framing focuses on the characteristics of images and their respective effects on readers and their sensemaking [13]. Most framing studies on photographs and illustrations [14], [15], [16], [17], [18] suggest that images hold a stronger framing effect than text alone. They can directly influence behavior and increase the likelihood of acting in response to the presented stimuli [18],

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[19]. Photographs especially hold a strong rhetorical power [15], [16], capable of permanently modifying readers' agenda, and impacting the perceived importance of a given issue [14]. While framing theory has been used to inspect rhetorical techniques in narrative visualizations [20], there is little empirical work on the difference in attitudinal effect between data visualization, illustration, and their combination in data stories.

We define attitudinal effects as a change in attitudes towards a specific topic. We focus our research on attitude changes as they can be considered a central effect of data stories. So far, there is limited understanding of the ways different types of visual representations can alter attitudes. The term attitude is regarded as how a person evaluates issues, objects, or other people [21]. Changes in attitudes can also be explained by the Elaboration Likelihood Model of persuasion [22], where persuasion plays an important role together with emotions [23]. On the other hand, for the change of attitude to be lasting, it must be accompanied by the formation of a satisfactory memory (information retention) [24], [25]. Therefore, as we seek to shed light on the attitudinal effects of visual representation in data stories, we will measure persuasion, emotion and information retention in an empirical study. We also consider it necessary to study these dimensions in combination, and not in isolation as has been done in previous visualization studies on emotions [e.g., 26, 27], persuasiveness [28], and memorability [e.g., 29, 30].

Furthermore, despite constituting essential components of articles, visual representations–in particular, information visualizations–are usually analyzed independently of their context, i.e., separate from the story text. Visualization scholars tend to construct laboratory settings to study the impact of journalistic data visualization on readers [e.g., 8], possibly as an attempt to contribute clear methodologies and results. However, we seek to understand the impact of visual representations in practice by studying them integrated with text. In this way, we try to maintain the ecological validity of the research.

We also contribute to an improved understanding about the attitudinal effects of visual representations embedded in journalistic storytelling. Besides the effect on attitudes immediately after exposure, we are interested in the stability of changes, i.e., the change lasting over time. For this purpose, we present a web-based study of an instrumented data story with responses collected immediately before and after reading the story, and after a week. By comparing three different versions of the article (illustration-only, datavis, and combined) we observe how attitudes change based on which visual stimuli are present and how they are perceived when combined. We compare the effects of visualizations and illustrations on readers' attitudes along three crucial dimensions: persuasion, emotion, and information retention. Our findings suggest that data-driven articles, where information is visually rendered by charts and maps, have a higher impact on readers' attitude compared to articles containing illustrations alone.

II. Background

In this section, we first address the types of visual representations which are the focus of our research, how these have been studied previously and how our approach differs. We then review how persuasion, emotions and information retention play an important role in attitude changes.

A. Visual Representations

The communicative and rhetorical salience of visual representations have been studied across a variety of domains, including communication and journalism studies [e.g., 32] and information visualization [e.g., 20]. While journalists often integrate a variety of visual artifacts in their articles, previous studies tend to center on one type, for example, photographs, and their effects on readers [14], [15], [16], [17], [18].

In this study, we compare the effect of two common types of visual representations–visualizations and illustrations–in the context of journalistic storytelling. We chose them as two distinct visual representations that tend to be used in combination in infographics and data stories, and seem to serve distinct communicative functions. While data visualizations represent abstract data [33], illustrations depict concrete objects and scenes. Arguably, the former suggests a kind of evidence potentially based on official or scientific sources and which people see as impartial, therefore trusting them [34], [35], while the latter communicates a topic in a more figurative way. Moreover, it plays a role in several studies on visualization that, through different approaches, have given an account of their underlying communicative techniques and their relationship with visualization. Illustration has a space for embellishing visualizations, and therefore its uses have been debated. Some advocate removing them completely [e.g., 36] but other empirical studies show that they improve information retention [8], [9]. The visual embellishment or uniqueness of a visualization can positively impact its memorability [8], [31]. Comparing different chart types, visualizations with strong aesthetic connotations are more likely to be retained and effectively recalled after a long period of time. Specific types of illustration have also been studied. For example, the use of pictographs in visualization can help people remember information during demanding tasks and entice them to inspect a visualization more closely [37]. However, another study observed that the use of anthropomorphisms in visualization has similar effects in eliciting empathy and prosocial behavior compared to standard charts [11]. Our approach differs from prior studies, as it seeks to first identify the effects of illustration and visualization separately and then in combination.

B. Attitudinal Change

According to Petty [21]: "The term attitude is used to refer to a person's overall evaluation of people (including oneself), objects, and issues". They can be evaluated either positively or negatively. Consequently, attitude change means that the previous evaluations of an individual are modified.

One attitude changing method is through *persuasion*: the act of providing additional, new or contradictory information to modify individuals' evaluation of the topic at hand [21]. Consequently, persuasion can be understood as a quality of information which makes change in initial attitudes possible. While it can be achieved through analytical reasoning or emotional appeal [38],

persuasion is often described as the process to influence other humans to adopt new attitudes, opinions, beliefs, or to change their behavior altogether [39]. In social psychology, persuasion is believed to play a key role in how people make choices and perform actions [21]. The foundations of the most widely accepted theoretical model of persuasion is ELM (Elaboration Likelihood Model), which relies on personal relevance ascribed towards a topic [22]. The role of visualization in persuading viewers has been addressed in different domains, including environmental governance [40], climate change [41], [42] and human rights [43]. Pandey et al. [28] experimentally studied the persuasive power of visualization, and identified that charts rather than tables lead to higher persuasion when participants do not possess a strong initial attitude about the topic. However, when they have a strong initial attitude they are less likely to be persuaded.

Attitudes are also strongly influenced by *emotions*. According to ELM, emotions can modify attitudes depending on the total elaboration level of the message [23]. When individuals' ability for elaboration is low, emotions have a high impact on attitude. However, even when the ability for elaboration is high, emotions can still impact persuasion by using the feelings which people have as argument, biasing the overall cognitive process. This happens because emotional arguments are formulated to cause people to like or dislike their own thoughts (affective validation) or to feel more confident or doubtful (cognitive validation) [23]. Generally, emotions are understood as requiring less elaboration effort. When subjects do not have strong initial beliefs on a particular topic, they elaborate stimuli peripherally [44]. In this regard, images are proven to have a higher emotional impact than text [45]. Readers connect more quickly with visuals and tend to be more persuaded [18]. In general, stories enriched by visual artifacts, specifically photographs, tend to foster a stronger emotional response in readers and lead them to permanently change their attitude [19]. The types of images influence the framing effects for the same topic. The emotional valence of certain stimuli impact the way readers retain information and form opinions [17]. Emotions play a fundamental role in making sense of numeric and complex data as well [26]. The temporal and geographic proximity of a topic and the personal, educational and political background of a viewer can greatly influence the emotive impact of a visualization [27], [46]. Recently, approaches that value the inherent affective aspects of data visualizations have emerged, devising guidelines to explicitly foster emotions in readers and render critical topics more actionable [47], [48].

A central aspect of attitudinal change is its longevity, i.e., *information retention*. Attitudes are represented in memory as summary evaluations associated with the attitude object [49]. People tend to have better memory for negative than positive stimuli [50]. In the news context, visual artifacts improve readers' ability to recall content [51]. Dual-mode presentation–when text is associated with images–performs better than single-mode, where only text is present [52]. The presence of images can distort memories. If incorrect pictures are associated with text, people are more likely to remember images and fabricate the content of the accompanying text [53]. There are a variety of studies concerning data visualizations and memory. Most of them focus on which elements are relevant for a visualization to be memorable: graphical and textual elements such as layouts, titles, and legends foster memory [29]. In particular, titles influenced the recalled main messages even though they can be misaligned with the message of the visualization [35]. In comparison to interactive visualizations, author-driven narratives may be more beneficial for data comprehension, but the difference in long-term information recall is unclear [30].

Another concept related to attitudinal changes and studied and studied in the visualization community is belief updating. Recent studies consider that prior beliefs held by people affect data visualization comprehension. These works apply Bayesian models to evaluate and explain belief updating from visualizations [54], [55], [56]. Our work, by contrast with those mentioned in this section, seeks to study the dimensions of persuasion, emotion, and information retention in combination, rather than in isolation.

III. Study Design

To better understand the effects of visual representations on readers' attitudes, we are interested in three central attitudinal dimensions: persuasion, emotion, and information retention. We created realistic journalistic content that participants would—and did—consume in their daily lives. We prepared three versions of an article that included different types of visual representations, and ran several evaluation phases to collect quantitative and qualitative data. This enabled us to compare the role of visualization and illustration in data stories, while exploring these visual representations' effects on readers. In particular, we are interested in the immediate and short-term change (or stability) of attitudes, emotions, and correct response rates.

A. Article Design & Visual Artifacts

We wrote, designed and developed one article that encapsulates different types of visual representations. This allowed us to ensure that participants had not read it beforehand. We also had precise control of the article characteristics that are relevant for the study. These include length, equivalent conditions in terms of content and visual representations, number of illustrations versus visualizations, simplicity of the visualizations, and other factors. The article is a long read introducing and discussing the Chilean water crisis. The topic was initially chosen because of its limited coverage in traditional media, despite the fact that it will have a major impact on citizens' daily lives over the next decade, and because when it does get discussed, it is often presented as a problem caused by climate change alone. These two characteristics left us room to explore the topic further, and to devise an engaging way of presenting the content. To better understand the topic, we read scientific studies and public reports from various sources (e.g., NGOs, governmental institutions and international organizations). These revealed different reasons for causality that are not clearly delineated in the public debate. We structured our article to revolve around four selected arguments: water management inefficiency, mining as a disrupting human activity, social inequality among the Chilean population, and

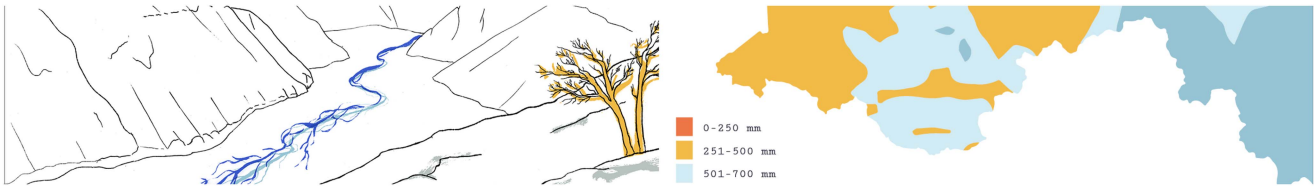

Fig. 1. Two distinct visual representations embedded in a data story about the water crisis in Chile: an illustration of an almost dried up riverbed (left) and a visualization of varying rainfall in a territory (right).

governmental responsibility in shortcomings. Our main goal was to build a convincing narrative thread, to persuade readers of how different problems contribute concurrently to the Chilean water crisis. We intended to convey the complexity of the problem at hand, instead of focusing on one single argument.

To develop a strong and convincing narrative thread, we organized a workshop with experts in hydrology, law, geography, and economics. The insights and ideas generated during this workshop informed our story design and development, including the visualizations and illustrations. The first draft of the article was written to provide geographical and social context for the water scarcity problem in Chile. Later on, we hired a journalist, who integrated new sources and edited a version of the text ensuring a journalistic and appropriate language for a general audience. The final outcome is a long-read article (2,500 words approximately) divided into four sections, plus introduction and conclusion. Each section addresses a different dimension of the water problem: droughts, mining, social inequality, and institutional mismanagement (See Fig. 1). Illustrations and visualizations were designed to match and complement the individual sections' content, following a fairly simple style.

- *Illustrations*: We included four illustrations in the article along with the header, which is a combination of the individual designs. We invited an illustrator, who in an iterative process proposed an illustration for each section of the article. The aim was to develop images that visually summarized and represented the content of each section. Some illustrations depict concrete elements (e.g., the impact of droughts and human activities on the landscape), while others present abstract concepts (e.g., unequal water distribution, institutional power and shortcomings).
- *Visualizations*: In total the article includes 12 visualizations—3 maps, 3 infographics, and 6 charts—most of them static. Four of them use readers' scroll position to change their status and trigger animations. For each section, we designed one main visualization. In the introduction and conclusion we added secondary graphs (see Fig. 2). They were designed by one of the authors, who is a data visualization professional. We aimed to make these visualizations as realistic as possible, so we drew on current trends in major newspapers as a reference. We conducted a survey of data stories about water issues where the use of maps and infographics is persistent [e.g 57,58,59].

  We follow essential characteristics of data stories, in order to maintain a realistic design with an alternation of text, data visualization and other elements (e. g., illustration, photograph, video) in a sequential structure. Data visualization in particular is often positioned close to the key arguments of the article, in order to provide readers with empirical evidence [6]. Illustrations are usually included to provide readers with visual context and clues about the story. Combining text, illustrations and visualizations, we generated three different versions of the same article. Each version contained the same base text (with some minor modifications in condition A which are explained below), while the selection of visual representations varied: Version `A` contained only illustrations, version `B` contained only visualizations, and version `AB` combined both illustrations and visualizations.

  The visualizations in the article present information that is not found in the text, leaving the illustration-only condition unbalanced in terms of content. We solved this by developing the contents equivalently between conditions. That is, we took the information contained in the visualizations of conditions B and AB and integrated it as text in the illustration-only condition (`A`). This ensured that regardless of the version and the way the information was presented, readers had access to the same content. As an example, in condition `B` and `AB` we included a map of Santiago showing the amount of liters consumed per person per day. This same data was added in a text paragraph in condition `A` (for the details of this translation, see the supplementary material), available online. We applied the same strategy in all situations where we observed content imbalances between conditions.

B. Hypotheses

To address our general research question—What are the effects of data visualization compared to illustration in data stories on readers' attitudes?—we formulated six hypotheses, based on previous studies about persuasion, emotions, and memorability:

H1: Just after reading the article (`t1-t0`) the effect on attitude is higher in conditions with visualizations (`B, AB`) compared to the one with illustration only (`A`).

H2: Just after reading the article (`t1-t0`) the effect on emotions is higher in conditions with visualizations (`B, AB`) compared to the one with illustration only (`A`).

H3: Just after reading the article (`t1-t0`) the correct response rate is higher in conditions with visualizations (`B, AB`) compared to the one with illustration only (`A`).

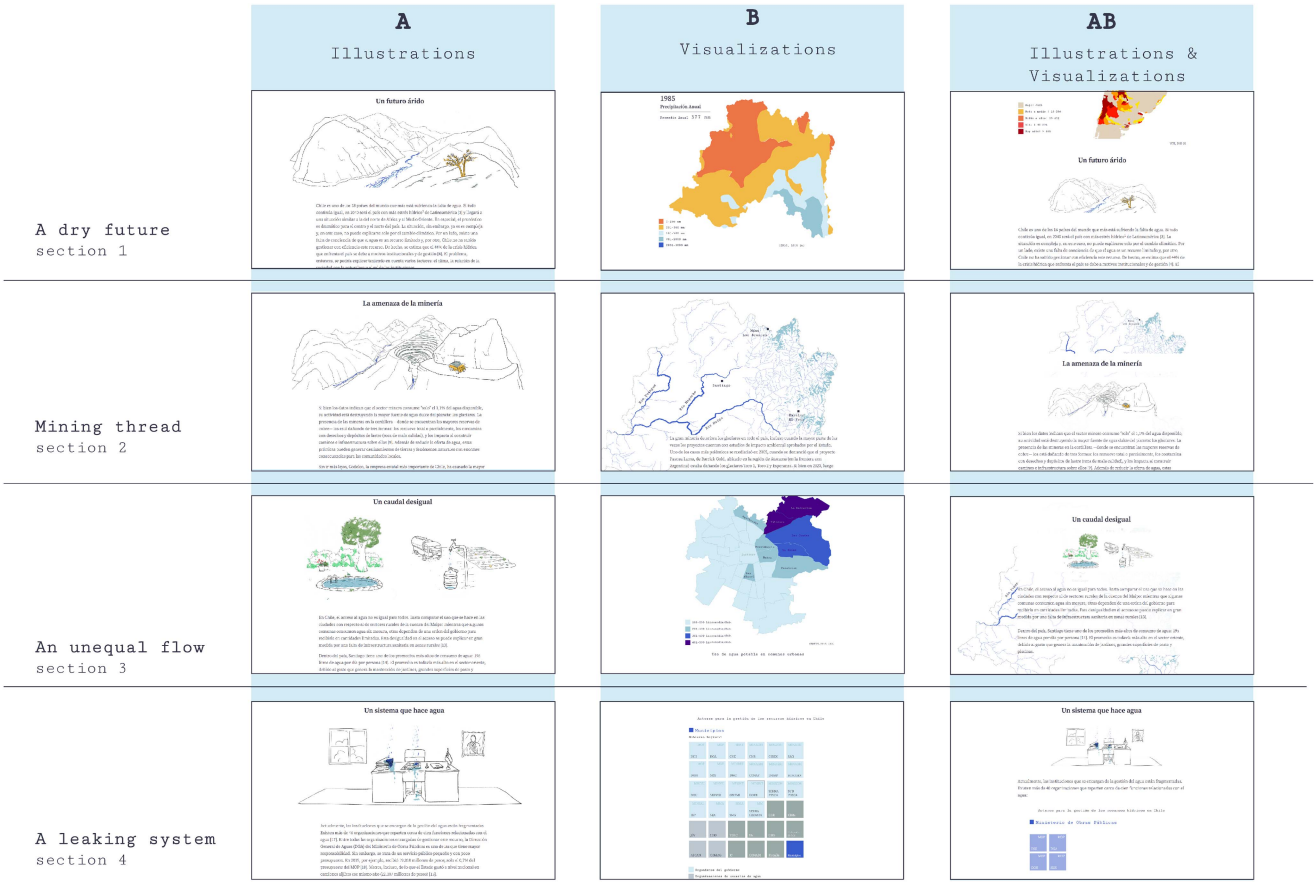

Fig. 2. We implemented three versions of the same data story on the water crisis in Chile: Participants read one of three versions; version A with illustrations only, version B with visualizations only, and version AB with both. The narrative of the data story was organized in 4 sections (A dry future, Mining thread, An unequal flow, A leaking system). In the figure we present screenshots of each section. showing how visual representations are related with text in each condition (A, B and AB). The complete stories can be seen in the supplementary material, available online.

H4: One week after reading the article (t2-t0) the effect on attitude is higher in conditions with visualizations (B, AB) compared to the one with illustration only (A).

H5: One week after reading the article (t2-t0) the effect on emotions is higher in conditions with visualizations (B, AB) compared to the one with illustration only (A).

H6: One week after reading the article (t2-t0) the correct response rate is higher in conditions with visualizations (B, AB) compared to the one with illustration only (A).

C. Experimental Design

To evaluate different versions (with ethics board approval), we used a between-subjects design. We compared three versions of the article with the visual representations described above. We decided not to include a text-only version for two key reasons. The first is that we sought to measure differences in effect between visual representations (visualizations and illustrations) and not to compare measurements against text alone, based on other similar studies that have done so previously (e.g [60]). The second is that our study seeks ecological validity, and in a real context, long-read articles usually combine different kinds of visual support [61].

Each participant was randomly assigned to one of the three versions of the article. We divided the study into three separate observational phases (see Fig. 3). Participants had to answer the first phase before (t0) and the second one right after (t1) reading the article. After 5 days, we sent them an email with a link to complete the study. They returned to answer the third phase one week late on average (t2). It is important to mention that this study is based on a single article with three versions, so its results are specific to the content presented. For external validity, it will be necessary to repeat this study comparing articles with different topics. However, we are moving toward a better understanding of visual representations' effects on data stories.

1) Apparatus and Participants: A call for participants was spread over social media. Authors used their institutional and personal profiles across various platforms to involve potential readers. Participants had to be at least 18 years old and live in Chile. The entire study was conducted in Spanish. In total, we recruited 198 participants, 133 of them fully answered t0 and t1, 71 also answered t2. Among the total of 133 participants, 61 identified as women, 70 as men, and 2 as gender-diverse. In their educational background, 58 participants reported a high school degree, 32 participants reported a college degree, and 41 a graduate degree. The participants' ages ranged between

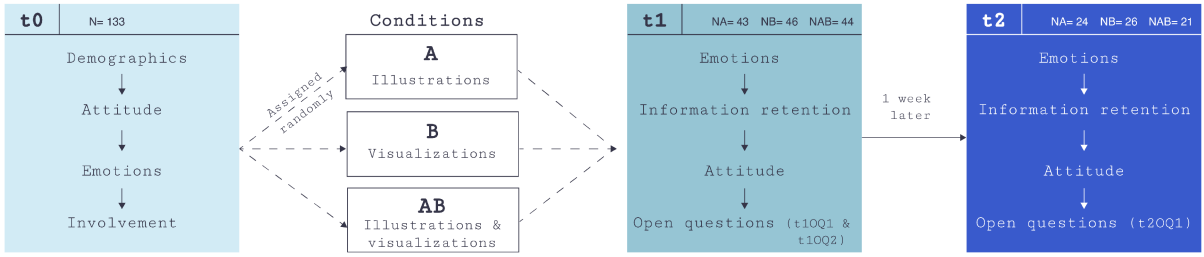

Fig. 3. The study is structured into three main observational phases: before reading the article (t0), just after reading the article (t1), and a week after reading the article (t2). N corresponds to the number of participants for each phase (t0, t1, t2) and in each condition (A, B or AB). Subsequent analysis is performed by observing the difference among the results obtained between t1 and t0 (t1-t0) and then the difference between t2 and t0 (t2-t0).

18 and 67 years. They were distributed as follows: 66 people aged 18-25 years, 27 between 26-36, 29 between 36-55, and 11 between 56-67 years. The participants' occupations fell into various categories: students (69), academics (8), architecture-design (22), technology-engineering (13), social sciences (9), and others (12). Participants used their own personal computers to read the article and answer the questionnaire. The article was blocked for mobile access. There was no financial compensation for participating. All participants voluntarily took part in the study.

2) Procedure: Participants accessed the page by clicking a link and accepting an informed consent page, after which they began the study.

- t0— *before reading the article*: The initial questionnaire included 10 questions in total. Four concerned demographics such as participants' age, gender, education, and occupation. An additional field asked to store participants' email for the follow-up questionnaire at t2. One question concerned the initial attitude of the participant about the topic, followed by a rank of water crisis causes. A third question assessed their emotional drive regarding the water crisis topic. We ended by asking three questions about their involvement concerning the topic. After this first questionnaire, participants were randomly assigned one version of the article and asked to carefully read it through.
- t1— *just after reading the article*: After reading the article, participants had to answer the second questionnaire consisting of 9 questions. This evaluation round was structured by combining old questions from t0 with new ones. We started by re-assessing participants' emotional drive towards the topic. We then formulated four closed questions with specific types of information they retained, according to each section of the article. We drew from t0 again and asked participants about their attitude towards the topic, followed by a ranking where they had to order the causes of the water crisis. Finally, participants were presented with two open questions. The first asked them to reflect on the images presented in the article, the second one prompted them to leave suggestions and comments. After finishing t1, participants could leave the page. After 5 days they were notified about the third evaluation phase (t2) via the email they provided during t0.
- t2— *about a week after reading the article*: Participants received a personalized link to complete the final questionnaire. The time lapse between participants answering t1 and t2 varies, since they decided whether and when to complete the study, and when they decided to return to the third and last step. In this phase, participants did not read the article again before completing the six questions of the questionnaire. At this step, we repeated the questions asked in t1, and included an open-ended question about what they recalled from the article.

We collected time data for each phase of the study with similar results across conditions; A (t1-t0: 27.96 minutes, t2-t1: 6.9 days), B (t1-t0: 25.35 min., t2-t1: 8.3 days), AB (t1-t0: 26.54 min., t2-t1: 8.1 days). During the study, participants were limited and could not navigate back to previous pages. This ensured that respondents' answers were neither reviewed nor changed from t0 and t1.

D. Measures

The questions were formulated to measure the attitudinal effects of visual representations along three axes. For each one, we applied methods extensively used in prior studies.

Change in Attitude. In their research, Pandey et al. [28] developed a method to effectively measure attitude changes linked to data visualizations. The authors included a question to measure attitudes on a given topic before and after administering persuasive stimuli. Questions vary according to the topic, but they are always formulated in the same way: *"to what extent do you agree that [...]"* followed by topic-specific statements. They measured answers on a Likert scale ranging from -3 to +3. In our study, the question to measure attitude was asked in all phases, posed as: *Given what you know about the water crisis in Chile, to what extent do you agree (or disagree) that it can be solved?* We used t0 as an initial benchmark to measure participants' prior involvement with the Chilean water crisis. Moreover, since we created journalistic content in a long-read format, we added a second question to find the reasons that may produce changes in attitude. This question enlisted potential causes for water scarcity, which readers had to rank according to perceived relevance. Again, the question was repeated in all phases. To avoid ordering biases, options were shuffled and presented to readers in a random order.

Change in Emotions. Psychology scholars have devised a wide variety of instruments to measure emotions. One of the most widespread is the Positive Affect and Negative Affect Schedule (PANAS) [62], which consists of a 20-item self-reported questionnaire to measure both positive and negative emotions. Among the various versions, we chose the International PANAS short form (I-PANAS-SF) [63] because of its brevity, with only 10 items. This tool describes adjectives associated with habitual feelings and emotions; upset, hostile, alert, ashamed, inspired, nervous, determined, attentive, afraid, active. The response format is a Likert scale, with a range from 1 (not at all) to 5 (extremely). For our study, carried out in Spanish, we used the validated Chilean translation of PANAS [64]. In the questionnaire, we applied the question as: *"According to what you know about the water situation in Chile, how do you feel about this reality?"* We asked the same question in the three phases `t0`, `t1` and `t2`. This allows us to compare the change in emotions produced by different treatments between `t0` and `t1`, and subsequently between `t0` and `t2`.

Comprehension and Information Retention. After reading the article (`t1`), participants were asked about the content. We developed four questions to assess information comprehension and retention. We included the same questions in `t2`, to compare the rate of correct answers.

E. Qualitative Evaluation

We collected participants' responses to the article content and format through open-ended, free-form questions in `t1` and `t2`. Immediately after reading the article, participants were asked open-ended questions about the visual representations' utility (`t1-OQ1`), and whether they wanted to share any other comments (`t1-OQ2`). We chose utility as a framing to encourage participants to express their own values in the context of data visualizations [46]. One week later, participants were asked to recall any story elements—image, idea or a particular bit of information (`t2-OQ`). Of the 133 valid participants in this study, 129 answered question (`t1-OQ1`), while only 72 answered question (`t1-OQ2`). In the following phase of the study (`t2`), 64 answered question (`t2-OQ`).

We began to examine the responses by defining guiding questions to help the research team decide what we wanted to know: What were the effects of visual representations in data stories on readers? Can we compare differences between the two types of visual representations: illustrations (`A`), visualizations (`B`), or the use of both (`AB`)?. In `t1`, we sought to identify the visual representations' immediate impacts on participants' reading experience. Analysis of the responses in `t2` would tell us about the lasting impact on readers' memory of the visual representations and the content of the text. We grouped the answers according to their study phase (`t1` and `t2`) and the article version the respective participant had read (`A`, `B` or `AB`). The analysis of each answer set was carried out independently.

The research team generated a categorization scheme for each of the answer sets, and used those schemes to code the participants' responses. This was complemented by frequency analysis around the occurrence of each code [65]. We used the following process:

1) Two members of the team iteratively analyzed the answers to code and categorize them until we believed that a saturation point was reached.
2) Independently, a third coder used the categorization proposed in the previous step to encode all the answers. During this process, few new codes were identified.
3) This coding system was returned to the two team members mentioned above, who reviewed it and generated the final categorization of the answers.

IV. Results

Overall, we collected 133 answers for phase (`t1-t0`) and 71 answers in the follow-up survey at (`t2`). Subjects were divided into three groups balanced by type of treatment; group `A` (illustration only) N_A=43, group `B` (visualization only) N_B=46 and group `AB` (illustration & visualization) N_{AB}=44. We conducted a post hoc power analysis using GPower software, assuming an α-level of. 05, an effect size of. 27 on attitude change and a statistical power of 80%. The effect size of. 27 was estimated based on a previous study [28], which compared the attitude change of tables versus charts on three topics and found effects between. 214 and. 538. Thus, we determined that a sample size of 75 subjects per cell was needed to detect a significant effect, which made our study slightly underpowered (71 answers). In the case of emotions, we did not conduct either an a priori or a post-hoc power analysis, so we can not claim that our study had enough power to detect significant effects related to emotions. 5 days after participating in the study, we sent the participants a link to fill the follow-up survey (`t2`). Participants two days to answer it on average, i.e., about a week after (`t1`). We also added three questions at the beginning of the study (`t0`) regarding readers' involvement in the water crisis. This was a way to identify differences among readers that could affect the results. The results showed no differences between conditions. To ensure that readers were paying attention, we observed the measurements we conducted on information retention as well. As shown in plots (j) and (k) in Fig. 4, readers mostly gave 2 or 3 correct answers in each of the conditions. This suggests that readers were paying attention when reading the articles. The final number of participants who completed the full study (t0, t1 and t2) was: N_A=24 (44.1% attrition), N_B=26 (43.4% attrition) and N_{AB}=21 (52,2% attrition). This dropout rate is reasonable for analysis, considering that the average dropout rate reported in Web-based health interventions was close to 50% [66]. The quantitative and qualitative analyses conducted on the responses in two phases are described below.

A. Quantitative Analysis

We base our analysis on 95% bootstrap confidence intervals (CIs) [67]. CIs are frequently used in visualization studies [68], [69], [70], [71] and are recommended over p-values [72]. We analyzed the change in subjects' attitude towards the water crisis and their reported emotions before the study and immediately after study (`t1-t0`), a week after the study (`t2-t0`), as well

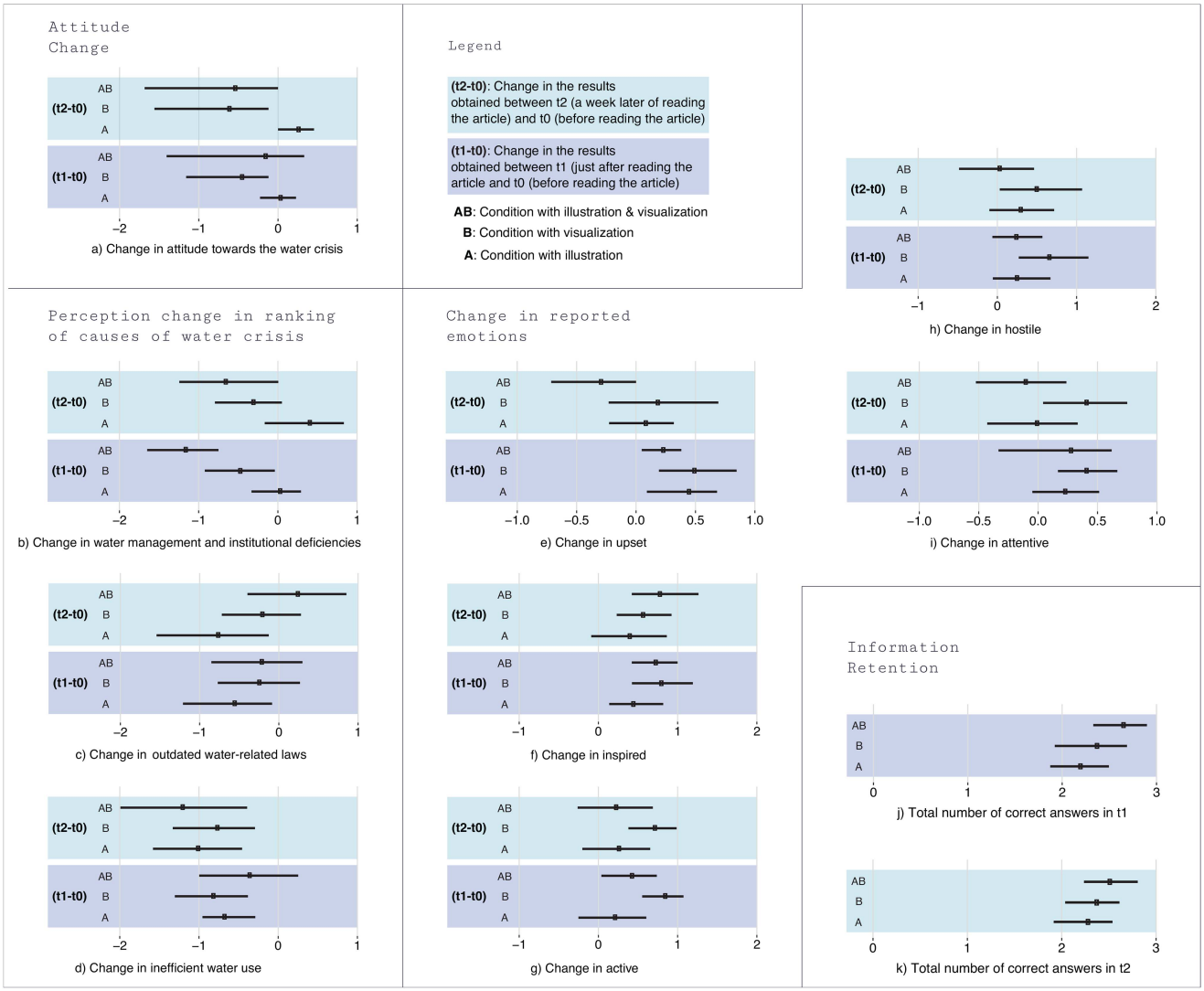

Fig. 4. (a) Change in attitude changes towards the possibility of a solution to the water crisis for each condition. (b), (c) and (d) (e) Perception change in ranking of water crisis causes. (f), (g), (h) and (i) Change in reported emotions of "upset", "inspired", "active", "hostile" and "attentive", respectively. Plots from (a-i) reported each condition (A, B, AB) comparing between (t1-t0) as well as (t2-t0). (j) Total number of correct answers per condition in t1 (just after reading the article). (k) Total number of correct answers per condition in t2, one week after the study took place. We observe no significant difference among conditions, but a slight trend showing that condition AB (illustration & visualization) increases retention compared to conditions A (illustration only) and B (visualization only).

as performance in questions measuring information retention just after the study (t1) and a week later (t2). Fig. 4 shows the normalized sample means together with 95% BCa CIs based on 10,000 bootstrap replicates. For the interpretation of the statistical significance of the overlap of CI error bars we refer to Krzywinski and Altman [73]. All the detailed results can be found in the supplementary materials together with the statistical analysis, available online.

1) Attitude: We compare the change in attitude through the question *Given what you know about the water crisis in Chile, to what extent do you agree (or disagree) that it can be solved ?* We asked this question in t0, and repeated in t1 and t2. This allowed us to compare the change between them, thereby identifying attitudinal changes regarding the subject. The hypotheses on attitude change stated that the effect is higher on conditions with visualization (B & AB) compared with the condition with only illustration (A) in both hypotheses (H1) immediately after reading the article (t1-t0) and (H4) a week later (t2-t0). The results show that H1 and H4 are supported only with condition B. In other words, when comparing different conditions, we see that the article with only visualizations (B) has a greater effect on readers just after reading it (t1-t0), and it persists a week later (t2-t0), producing a greater change of attitude regarding the water crisis in Chile.

Fig. 4(a) reports the results of the primary question measuring a change in attitude towards the possibility of a solution to the water crisis. It represents the change among the results obtained between t1 and t0 and then between t2 and t0 for each condition. When we analyse condition A, we do not see changes between t1 and t0 or between t2 and t0, since both the CIs include 0 as shown in Fig. 4(a). In other words, there was no significant attitudinal change in the condition with illustrations

only (A), neither immediately after reading the article *(Mean (A(t1-t0))= 0.045, 95% CI = [-0.23, 0.23])*, nor a week later *(Mean (A(t2-t0))= 0.273, 95% CI = [0.00, 0.45])*. Meanwhile, in condition B we observed a significant change immediately after the treatment *(Mean (B(t1-t0))= -0.440, 95% CI = [-1.16, -0.12])*. That is, after reading the article with visualizations we observed an effect of condition B as a change in the perception regarding the solution of the water crisis. This change in attitude has a negative trend, meaning that after reading the article, participants believe that there is smaller chance of a solution to the water crisis. After one week, we observe that this effect holds on subjects under condition B *(Mean (B(t2-t0))= -0.600, 95% CI = [-1.52, -0.12])*. Finally, in condition AB there is no significant change in attitude right after reading the article with both illustration and visualization *(Mean (AB(t1-t0))= -0.158, 95% CI = [-1.37, 0.32])*. Likewise, we did not observe changes after a week *(Mean (AB(t2-t0))= -0.526, 95% CI = [-1.63, 0.00])*, but we noticed a larger variance in attitude change compared to the small variance in condition A, already mentioned above.

To inquire about the reasons that may produce the change of attitude, in a second question we asked readers to rank five causes of the water crisis: "drought and decreased precipitation", "water management and institutional deficiencies, "outdated water-related laws", "inefficient water use", and "inequality in access to water". The results show significant change in three of the causes as shown in Fig. 4(b)–(d). Readers deem the cause "water management and institutional deficiencies" (Fig. 4(b)) to be more relevant to the water crisis after reading the article. It increases in importance (ranking) significantly just after reading the articles (t1-t0) containing visualizations; For condition B *(Mean (B(t1-t0))= -0.462, 95% CI = [-0.92, -0.038])* and for condition AB *(Mean (AB(t1-t0))= -1.150, 95% CI = [-1.65, -0.750])*. However, this change of perception does not hold after one week (t2-t0) in any condition. Meanwhile, when we observe the cause of "outdated water-related laws" (Fig. 4(c)) we notice that it increases in importance significantly only in condition A (with illustration only) just after reading the article *(Mean (A(t1-t0))= -0.54, 95% CI = [-1.21, -0.083])*, and this effect is maintained a week later *(Mean (A(t2-t0))= -0.75, 95% CI = [-1.54, -0.125])*. Interestingly, the cause of "inefficient water use" (Fig. 4(d)) decreases in importance just after reading the article only in condition A *(Mean (A(t1-t0))= 0.042, 95% CI = [-0.33, 0.292])*, but it does not hold after one week *(Mean (A(t2-t0))= 0.417, 95% CI = [-0.21, 0.875])*.

Observing these results, we conclude that only condition B produces a significant and persistent change in attitude, but this effect cannot be explained only by changes in perceptions of the reason behind the water crisis. Although we observed that the cause "water management and institutional deficiencies" produces significant differences for condition B, it does not persist one week later (t2-t0). Therefore, the next step is to analyze other dimensions that can help us explain the change in attitude; emotions and information retention.

2) Emotions: For this study, we measured 10 different emotions following the instrument (I-PANAS-SF) (see Section II-I-D). The hypotheses on the change in emotions stated that the effect is higher on conditions with visualization (B & AB) compared with the condition with only illustration (A) in both (H2) immediately after reading the article (t1-t0) and (H5) a week later (t2-t0). The results support H2 only for the emotion "active". However, when we observe condition B separately, (H1) we see it is also supported for the emotions "hostile" and "attentive". H4 is also supported in condition B, for the emotions "inspired", "active", "hostile" and "attentive". When comparing different conditions, we thus see that the articles with only visualizations (B) have a higher effect on readers just after reading the article (t1-t0) and that this effect also persists after a week (t2-t0), producing a greater change of emotions compared to conditions with illustrations (A and AB).

We observed important changes in 5 of the emotions we measured, which appear in Fig. 4(e)–(i). Fig. 4(e) shows the changes produced in "upset". The effect corresponds to the change reported by readers just after reading the article (t1-t0) and by a week later (t2-t0). The "upset" emotion increased just after reading the article (t1-t0) in the three conditions, and vanished over time in all three conditions. The mean changes of the emotion "upset" for the three conditions are the following: For condition A in (t1-t0) *(Mean (A(t1-t0))= 0.455, 95% CI = [-0.091, 0.68])* and in (t2-t0) *(Mean (A(t2-t0))= 0.091, 95% CI = [-0.227, 0.32])*; for condition B in (t1-t0) *(Mean (B(t1-t0))= 0.500, 95% CI = [0.192, 0.88])* and in (t2-t0)) *(Mean (B(t2-t0))= 0.192, 95% CI = [-0.231, 0.73])*; finally in condition AB in (t1-t0) *(Mean (AB(t1-t0))= 0.238, 95% CI = [0.048, 0.38])* and in (t2-t0) *(Mean (AB(t2-t0))= -0.286, 95% CI = [-0.714, 0.00])*.

On the other hand, Fig. 4(f) illustrates the changes produced in "inspired". Here we see that after reading the article (t1-t0) participants felt more inspired in all conditions. However, unlike "upset", the effect on this emotion remained stable after a week (t2-t0) only in conditions with visualization (B & AB) since we observe that the CI bars for these conditions do not touch 0. The mean changes of the emotion "inspired" for the three conditions is the following: For condition A in (t1-t0) *(Mean (A(t1-t0)= 0.45, 95% CI = [0.136, 0.82])* and in (t2-t0) *(Mean (A(t2-t0))= 0.41, 95% CI = [-0.091, 0.86])*; Meanwhile for condition B in (t1-t0) *(Mean (B(t1-t0))= 0.81, 95% CI = [-0.423, 1.15])* and in (t2-t0) *(Mean (B(t2-t0))= 0.58, 95% CI = [0.269, 0.92])*; Finally for condition AB in (t1-t0) *(Mean (AB(t1-t0))= 0.74, 95% CI = [0.421, 1.00])* and in (t2-t0) *(Mean (AB(t2-t0))= 0.79, 95% CI = [0.368, 1.26])*.

When analyzing the emotion "active", we see that there is a change between the conditions with visualization (B & AB) and the one with only illustrations (A). Fig. 4(g) shows that this emotion increased in readers, after reading the article, in condition B *(Mean (B(t1-t0))= 0.87, 95% CI = [0.58, 1.09])* and in condition AB *(Mean (AB(t1-t0))= 0.45, 95% CI = [0.05, 0.75])*. After one week this state was maintained only for condition B *(Mean (B(t2-t0))= 0.74, 95% CI = [0.39, 1.00])*. The emotion "attentive" as shown in Fig. 4(i), increased just after reading the article only in condition B *(Mean (B(t1-t0))= 0.417, 95% CI = [0.167, 0.67])* and remained a week later, *(Mean (B(t2-t0))= 0.417, 95% CI = [0.042, 0.75])*.

When analyzing the remaining options (alert, ashamed, nervous and determined) we did not find significant changes. The

		Just after reading the article (t1-t0) Conditions			A week after reading the article (t2-t0) Conditions		
		A	B	AB	A	B	AB
Differences in attitude		No	Yes	No	No	Yes	No
Differences in emotions	Upset	Yes	Yes	Yes	No	No	No
	Inspired	Yes	Yes	Yes	No	Yes	Yes
	Active	No	Yes	Yes	No	Yes	No
	Hostile	No	Yes	No	No	Yes	No
	Attentive	No	Yes	No	No	Yes	No
Information retention		No	No	No	No	No	No

Fig. 5. Summarizes the effects on change in attitude, emotion, and information retention observed when comparing the three conditions (A, B & AB) in the two phases of the study (t1-t0) and (t2-t0). Primary (P) and secondary (S) questions were used to measure attitude.

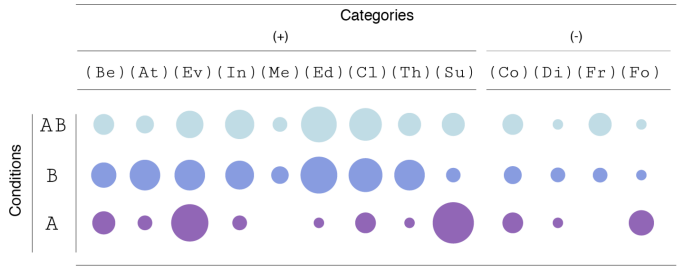

Fig. 6. Summary of the 13 categories that emerged from analyzing the open-ended responses (t1-OQ1) about visual representations' usefulness. These categories are organized by positive (+) and negative (-), where: (Be: Beautiful), (At: Attention-grabbing (Ev: Evocative), (In: Intelligible), (Me: Memory), (Ed: Educational), (Cl: Clarifying), (Th: Thrilling), (Su: Supportive), (Co: Confusing), (Di: Distracting), (Fr: Frustrating) and (Fo: Forgettable). Circle size represents these categories' occurrences in each of the conditions (AB, B, A).

result of this analysis can be found in the supplementary materials, available online, (Section 2.1.2). As a summary, Fig. 5 shows the conditions in which we see changes for each measurement in the study. Looking at the changes in each of the emotions reported between the different phases of the study, we see that condition B (with visualization only) shows changes for five emotions just after reading the article (t1-t0). In other words, the condition with only visualizations triggered a higher emotional response compared to the conditions with illustration (A & AB). On the other hand, the effect on these emotions was persistent one week later (t2-t0) for all emotions in which a change is observed, except for the emotion "upset".

3) Information Retention: The retention results show no significant effect from the different types of conditions with which participants interacted. Just after finishing the study t1, as shown in Fig. 4(j), we see no significant changes in the number of correct answers: For condition A *(Mean (A(t1))= 2.2, 95% CI = [1.9, 2.5])*; for condition B *(Mean (B(t1))= 2.4, 95% CI = [1.9, 2.7])* and finally for condition AB *(Mean (AB(t1))= 2.7, 95% CI = [2.3, 2.9])*. When analyzing the results of these same questions on t2 we observed a slight decrease in the number of answers, but it is uniform across conditions and non-significant. Moreover, in t2 no condition showed significantly better information retention than the others, either observing each question in isolation or in aggregation as shown in Fig. 4(k): For condition A *(Mean (A(t2))= 2.3, 95% CI = [1.9, 2.5])*; for condition B *(Mean (B(t2))= 2.4, 95% CI = [2.0, 2.6])* and finally for condition AB *(Mean (AB(t2))= 2.5, 95% CI = [2.2, 2.8])* In summary, the results do not appear to support H3 and H6.

B. Qualitative Analysis

This section presents major themes observed in the study questionnaires' free-form responses. After analysis of the question regarding visual representations' usefulness (t1-OQ1), 13 categories emerged, as shown in Fig. 6. These allow us to characterize visual representations' role for readers in better understanding or contextualizing the textual content. We then organized the responses into the elements remembered and the types of comments readers made about the data story in general. After each sub-category, we added a number in parenthesis representing their occurrence in the responses. We included some illustrative quotes from participants in the most relevant findings of this study as well. Quotes are reported and translated into English, with participant number and condition, e.g., [P123, AB]. OQ1 stands for Open Question 1.

1) Roles of Visual Representations: When analyzing responses to the question about the utility of the visual representations (t1-OQ1) the first thing we observe is that most readers in condition B explicitly stated that the visual artifacts were useful and impactful (39 out of 44). In condition AB answers are similar to condition B: 33 out of 42 readers found visual artifacts useful for their reading process. This differs from condition A where more than half of the readers (22 out of 40) deemed illustrations not or hardly useful for understanding the content. When analyzing these responses, different categories emerged which allowed us to identify the functionality that visual representations have for readers. We identified 9 categories that we consider positive and 4 negative. Across the three conditions, visual artifacts are described as having positive effects; they often have an aesthetic appeal, they draw readers' attention, and they provoke emotional reactions. However, they are also associated with negative descriptions at times, considered confusing or distracting, they can cause readers to feel frustration, or they are just forgotten. For instance, in condition A visual artifacts are found evocative (13) and supporting (16):

> *"The illustrations are beautiful, [...] I think they are useful [...] They complement each other very well and make the text easier to read"* [P14, A]

Readers consider them as a good addition to the text, helping them with placing and visually representing the concepts discussed in the text. However, artifacts in conditions A are not essential for readers, who do not rely on them to fully understand written content:

> *"[...] I don't think [the illustrations] were particularly useful for understanding the text"* [P113, A]

On the other hand, while readers consider illustrations to be beautiful (4), they often forget (7) about them almost immediately, or even find them confusing (4) and not well connected to text:

> *"[Illustrations] were very unimportant, as they didn't present a clear idea and didn't complement what the text said. [...] they do not help to better explain the information."* [P84, A]

When we observe the responses in condition B, readers consider the role of the visual artifacts as educational (12), clarifying (10), intelligible (7) and evocative (8). Charts are discussed as highly understandable and responsible for carrying essential information beyond the text. Their clarity helps readers in forming context and in changing attitudes or enriching their knowledge regarding the water crisis:

> *"I think [the visualizations] were useful because they explained, highlighted and allowed the reader to compare the data shown in the text, which sometimes don't seem important or are easy to forget."* [P82, B]

The statements about the visual representations in condition B are also largely favorable. Apart from receiving positive comments on their aesthetic presentation (6), visual artifacts are considered to have a remarkable influence on readers' attention (8) as well as on their emotional response (8). While negative effects such as confusion (3) and frustration (2) are present, their impact seems to be minimal compared with the positive aspects:

> *"They were useful for understanding the information, because visualizing water shortage is much more shocking than reading about it in the text."* [P8, B]

Similarly, in condition AB readers describe artifacts as educational (12), clarifying (10), intelligible (8) and evocative (7). Notably, for this condition, scores are almost identical to condition B. This is often due to how visualizations receive more attention and feedback. Readers exclusively refer to visualizations on 20 occasions. By contrast, illustrations are never discussed alone, but only in combination with or in subordination to visualizations:

> *"[Visualizations] give a clearer image of all the affected sectors, and the implications of the reduction in water reserves [...]"* [P66, AB]

Finally, in condition AB we face mixed reports from readers. It is difficult to define which effects are relevant, since the responses are quite diverse. Some of them considered artifacts to be aesthetically pleasing (4). When given visual representations of data, readers also reported feeling more impacted and thrilled (5) about the subject. However, negative effects seem to be slightly more incisive. Artifacts' density and interactivity is also deemed to be frustrating (5), while some visual elements are considered to be confusing (5).

> *"Some of them were quite useful and helped you not to get so tired reading; [...] to start with it was interesting, but after a while it made you a bit dizzy [...]"* [P80, AB]

2) Comments: With open question (t1-OQ2) the first thing we notice is that comments can be categorized into those referring to the contents of the article and those that refer to the format (visualizations, illustrations, interaction, etc.). In both categories we find opinions that can be categorized as suggestions, criticisms, and compliments. In all three conditions the comments mainly correspond to the format of the article. We see that condition A receives more comments on the contents than the others (A=11; B=5; AB=3). Most of their comments are content focusing on possible solutions and problems related to the water crisis, pivoting around concrete solutions and the will of the reader to discuss positive actions, and not only negative consequences. We found that these types of comments about the content correspond more frequently to suggestions and compliments, rather than criticism.

> *"[...] While [the article] doesn't seem to talk about management strategies to take care of water, I would love to see it address the impact that better city design, urban and rural irrigation systems could have [...]"* [P14, A]

On the other hand, the open-ended comments in conditions AB and B, refer more often to the format of the article. Although these comments correspond to suggestions, compliments and criticisms, we can observe that there is a tendency towards the latter. Condition B gathers the largest number of negative comments, usually targeting visual aspects of the charts or interaction features.

3) Recalled Elements: When analyzing the answers to question (t2-OQ), which was about recalling any story elements, we identified five sub-categories; illustrations, visualizations, textual content, emotions and specific data. Conditions A and AB present four illustrations associated with each of its sections. One example of the description is as follows:

> *"[...] Picture of mountains and drought in a mine – comparison of a garden with a swimming pool with one without water – President's desk with the 'leaky system' [...]"* [P7, A]

In condition AB, only one response mentions an illustration. When comparing both conditions (A and AB) we can observe that illustrations were less remembered by readers when they were presented together with visualizations. In condition B and AB, visualizations of different characteristics were presented: maps, graphs and diagrams. We do not observe many differences between what the readers remember. They all mainly described maps (16) and to a lesser extent, graphs (7) and diagrams (5). For example:

> *"the map of Santiago with the historical annual rainfall [...]"* [P21, AB].

Regarding the textual content of the article, in condition A, we observe that readers remembered it more frequently (14) while in condition B (7) and AB (10) it was somewhat lower. The destruction of glaciers is the topic with the highest recall across the three versions.

Finally, we also observed some responses about emotions that participants remember. Although there are not many (A=1; B=3 and AB=3) the statements in conditions B and AB are: "shocking", "devastating" and "frustration":

> *"I remember my feeling of powerlessness as I read the article. It was worse when the article visualized the number of people in Chile who are supplied by water trucks. [...] and the fact that a large number of*

the population do not have access to water is shocking [...]" [P13, AB]

Akin to the responses to question (t1-OQ), this suggests that the article versions with visualization elicit more emotional responses compared to the condition with illustrations only.

V. Discussion

Our results show that data-driven long reads, where information is visually rendered only by charts, have a higher impact on readers' attitude compared to long reads featuring illustrations. These findings pave the way towards further research on the effect of visualizations compared to illustrations in data-driven storytelling. We observe that the condition with only visualization (B) produces a change in attitude towards the water crisis just after reading the article which persists one week later, although with a decreasing effect size, as opposed to conditions with illustrations (A & AB). Similarly, our results show that the visualization-only condition (B) triggered the greatest number of emotions. With information retention, we did not observe significant differences among conditions.

The answers to free-form questions also offer insights on how readers approached artifacts across the three versions of the story. In regards to A, illustrations were neither considered particularly useful nor effective to understand the content. Readers found them beautiful, but struggled to retain them in the long term. This condition also elicits more content-oriented comments. Version B instead scored well when it comes to utility: readers considered visualizations an essential component of the story. They consequently also seemed to be more prone to report positive influences on their attention span and sense-making process. As opposed to illustrations, readers often remembered visualizations over text and were more likely to comment on them in the later phases of the evaluation. With version AB, it is interesting to notice that, although visualizations and illustrations were mixed, readers' answers were very similar to the ones for version B, suggesting the prominent role of visualizations over illustrations. Overall, illustrations seem to be less memorable and functional than visualizations.

A. Implications

When considering the results obtained in both the statistical and qualitative analysis, we reflect on the persuasive effects observed in the condition that include only visualizations (B). While this requires further analysis and experiments, we speculate that this effect is related to the emotional impact triggered by the visualizations, as well as being explained by the educational, clarifying, and intelligible role readers attributed to them. Through these roles, visualization becomes a tool facilitating readers' access to the information by making it more comprehensible. This suggests that data visualization is a more persuasive support for an argument than illustration alone. After observing the effects reported by readers under condition B, we found it revealing that visualization elicited more emotional responses. We suspect that visualization clarifies the information presented, generating an emotional connection and persuading the reader. This concurs with the idea that attitude change can be achieved through analytical reasoning, due to the evidence in the qualitative analysis, or emotional appeal based on the evidence in the quantitative statistical analysis [38].

Analyzing the impact produced by different types of visual representations showed us some patterns which, while they require further investigation, may have profound implications for their use in data stories. First, when we look at the changes in the order that readers gave to the causes of the water crisis, we see that the cause of "water management and institutional deficiencies", rose right after reading the article in the conditions with visualization (B & AB). This can be explained by the use of a particular diagram used in conditions B and AB (see supplementary material), available online, which represents the number and variety of actors involved in water management. This diagram may emphasize that particular idea. In the illustration-only condition there is no visual representation referring to this cause, and instead it is only presented as text. On the other hand, when looking at the cause of "outdated water-related laws" we see that it rises in the ranking in the condition with illustration only. By contrast with the cause "water management and institutional deficiencies," this cause has no visual representation (in any of the conditions) and is only referred to in the text. While this requires further investigation, we can say that readers in the A condition paid more attention to the text, and that on the contrary, readers in the B and AB conditions were persuaded by the visual representation associated with the "water management and institutional deficiencies" cause. Along the same line but focusing on data retention, when comparing the three study conditions we did not observe differences in the effects. However, in the answers to the open questions (t1-OQ2) and (t2-OQ), the readers in the condition with illustrations only (A) alluded mainly to the content of the article; while those in conditions with visualization (B & AB), mentioned the visualizations much more frequently. These two different findings could be important for designing a data story: Do we want readers to concentrate on the content of the article, or the form? If we want readers to focus on the article for its content rather than its visualizations, these may need to be less prominent. Complex arguments can be enhanced by visualizations, and by strategically choosing where to place and how to combine them. Reader retention may be stronger or weaker as a result. In any scenario, this aspect requires further investigation.

We find it relevant to the implications for visual representations use to observe the differences in the emotion "active" as well (see Fig. 4(d)). Here, we see that the effect on emotion change is larger in the conditions with visualization (B & AB) after reading the article, and persists one week later in the condition with visualization only. This result suggests that visualizations act as a "call to action", which might be relevant for authors of data stories who seek to trigger readers' actions toward the subject presented.

B. Limitations

Although our approach is effective and our results are promising, some limitations should be considered.

1) Measuring Emotions: According to our qualitative analysis, visualizations in particular elicit different emotional responses among readers compared to the emotion measured in the questionnaire of the study. This may be a result of the type of measurement we used (see Section III-D). While the issues presented in a data story vary widely, the instrument measures a limited number of emotions. It is possible that it does not accurately pick up the full spectrum of emotional responses that the story may elicit. For example, in the qualitative analysis some emotions reported by readers express: "frustration", "impact", "shocking", "devastating". None of these appear in the I-PANAS-SF questionnaire, though. Future work could complement this measurement with others that address specific emotions expected in response to a data story. On the other hand, the I-PANAS-SF only focuses on emotional valences, i.e., on positive and negative affect. Future studies could incorporate a two-dimensional space model spanning valence and arousal (intensity of the emotion) [74]. It is important to keep the length of the questionnaire limited, though, so as to avoid study fatigue in the participants.

2) Measuring Information Retention: Taking study fatigue into account, we attempted to measure information retention in a reduced setting. To make it less tedious for the participants, we used as few questions as possible. However, in light of the results obtained in the statistical analysis, we suspect that the questions that we formulated were limited to very specific contents, which were not necessarily sufficient to identify what the readers remembered more generally. The open questions included in both `t1` and `t2`, on the other hand, provided us with much more detailed information on what readers remembered. This suggests that future work should adapt and/or synthesize a procedure such as the one proposed by Bateman et al. [8] in their study on visual embellishment and memorability. In their work, a more detailed picture was gained from interviews about what the participants understood regarding the visualizations that they were shown, and what they remembered immediately afterwards or some weeks later. Although an interview is longer for the participants, and takes the researchers longer to analyze, it yields more detailed quality information. Depending on the length of the study, it needs to be balanced to obtain more complete measurement without generating fatigue among the participants.

3) Visual Representations Ratio, Dynamism, and Novelty: There are some considerable differences between how visualizations and illustrations are presented to our study participants: ratio and dynamism. The ratio between charts and illustration is not one to one, meaning that we included a higher number of charts (12) than illustrations (4). This asymmetry could potentially bias our participants to evaluate visualizations as more informative simply based on quantity. However, our results show that participants in `B` almost never consider smaller charts, and focus exclusively on main visualizations at the beginning of each section. Nevertheless, future studies should better consider the ratio of visual representations and ensure full symmetry among different settings. For dynamism, some visualizations benefit from animations, while the illustrations were entirely static. This is due to how different formats usually present information. "Scrollytelling" has become a common and recognized technique in data stories, and it is fairly common for visualizations to be dynamic. On the other hand, illustrations are often single static objects. Future work should concentrate on this difference, since animations could be more attractive for readers and ensure a similar treatment for different types of visual representations.

While visualizations are becoming more common in the context of journalism, they still require a different level of data literacy in comparison to static illustrations. The relative novelty of visualization compared to an assumed familiarity with illustrations may have some impact on persuasion and information retention.

Another aspect that should be observed is the particular characteristics and qualities of the illustrations and visualizations, which could have a differential impact on reader impressions of the topic. Poor-quality visual representations could lead to readers misunderstanding the information, thereby influencing the results of a study such as this. An exceptionally high quality design may also create a positive bias. Of course, each of the three conditions presents only one article design, which could have looked very different if created by another team in a different context. The purpose of this study was to examine three real-world news articles, each of which works as an informative data story about environmental issues. We have made every effort possible to create realistic and representative conditions; however, we fully acknowledge that this does not and can not present generalizable results covering other topics.

Another aspect to consider is the topic to be covered in the article. Some topics may benefit more from one type of visual representation than another, such as those that require both data representation and process explanation (e.g., creating a new vaccine, the effects of a hurricane, etc.). These articles could benefit from a clear illustration that explains a succession of facts. This opens up future work that could be oriented towards identifying the most appropriate visual representations (or combination of these) for particular topics.

4) Low Return Rate: The return rate of participants between `t1` and `t2` was relatively low. Since the third questionnaire is administered a week later `t1`, participants often drop out. Such dropouts could potentially jeopardize the last part of the study and weaken our findings on memorability. Given the consistent number of overall participants, the number of answers to `t2` is still enough to obtain preliminary results and carry out qualitative analysis on free-form answers. Nevertheless, future studies should consider possible ways to minimize attrition, possibly by establishing a reward system for participants or by effectively motivating them to come back and finish the study.

5) Free-Form Response: The open-ended questions we asked in the study may lead to a positive bias due to how we phrased them. For instance, the question (t1-OQ1) was phrased as: *Were (visual representation) useful for understanding the information given in the article?* Although the wording was identical for all three conditions, and its positive phrasing could uniformly extend to all, we recognize that a more neutral phrasing might reduce this potential bias. Further studies should consider this limitation.

C. Future Work

The results presented and discussed in this paper are a promising starting point for similar studies investigating other dimensions or comparing other types of visual representations. One aspect that could be further investigated is whether data visualizations activate readers to perform certain actions. *Given an explicit call to action (e.g., donation, sign a petition, etc.), would visualizations make data stories more actionable than illustrations?* Investigating this aspect could also help clarify why negative arguments generate positive emotional activation as in the case of our quantitative and qualitative results.

Another way forward could be to look at differences between photographs and visualizations with a similar approach. For instance, we could ask: *Do visualizations influence readers' attitude as strongly as photographs? If yes, how do they concur to change beliefs and habits?* This research branch could even expand to false memories: *How can visualizations manipulate readers' memories?* This particular question is becoming vital, in the light of repeated misuse of data visualizations in agenda setting and fake news.

Although the results we obtained are promising, they are based solely on one data story published in three variants. We consider that adding entirely different data stories and running a similar experimental study to test similar hypotheses would add more external validity to the conclusions. Future work could consider running a similar experiment with multiple stories that have multiple variations, for example, in textual length or topical scope. One could also consider extending the measurement and compare the differences between a text-only article and versions with different visual representations (e.g., videos, photos).

In this study, we found evidence of the effect of visualizations on attitude, but did not study in detail how the positioning of text and visual artifacts (visualizations or illustrations) may influence this outcome. The positioning and distribution of visual representations and text within a data story could influence reader attitude changes. Future research could consider studying the impact that visuals and their position may have, incorporating variables such as the semantic and spatial proximity of visual representations to text. Finally, in order to separate the effects of visual conditions compared to previous knowledge of the topic, we also suggest including questions to assess participants' expertise about the water crisis.

VI. Conclusion

As journalistic forms of storytelling change to accommodate a wide range of contents including data, visualizations play an ever-increasing role for informing about issues of public concern. There has already been considerable research on other visual representations in news media, but there has been little evidence on visualizations' effect on attitude changes. With this research we attempted to get a better understanding of the persuasive, emotive, and memorable qualities of visualizations compared to illustrations when embedded in long read articles. We researched the role of visual representations via one particular data story about a current topic that proved to be a promising strategy. We formulated 6 hypotheses in order to test different visual artifacts' effects (visualization compared to illustrations and their interaction) upon attitudinal change, emotions, and information retention by conducting a user study. Our main conclusions are summarized as follows. With this research we contribute insights on the attitudinal effects of visualization both in comparison to and in combination with illustration. First, our results suggest that using only visualizations within a data story can have a significant effect on attitudinal changes. Second, they can also trigger a higher number of emotions, which leads us to think that the change in attitude may be related to the emotional impact they generate, even though claiming this relationship needs further research. Third, visual representation type has no statistically significant effect on information retention; however, the qualitative analysis has provided evidence of a considerably higher level of detail and elaboration in the free-form responses regarding articles which feature visualizations. These are important indications about the attitudinal effect of visualizations, in particular regarding complex issues such as environmental crises. During this research we came across multiple open issues, which we address in our limitations and consider to be an interesting starting point for future work. Thus, while our results are not fully conclusive, we see a great need for this line of research on the rhetorical power of visualizations in the context of storytelling.

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