# Storytelling in Information Visualizations: Does it Engage Users to Explore Data?

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## ABSTRACT
We present the results of three web-based field experiments, in which we evaluate the impact of using initial narrative visualization techniques and storytelling on user-engagement with exploratory information visualizations. We conducted these experiments on a popular news and opinion outlet, and on a popular visualization gallery website. While data-journalism exposes visualizations to a large public, we do not know how effectively this public makes sense of interactive graphics, and in particular if people explore them to gain additional insight to that provided by the journalists. In contrast to our hypotheses, our results indicate that augmenting exploratory visualizations with introductory 'stories' does not seem to increase user-engagement in exploration.

### Author Keywords
Narrative visualization; storytelling; social data analysis; engagement

### ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

## INTRODUCTION
In this article, our interest is to assess whether augmenting exploratory information visualizations with initial narrative visualization techniques and storytelling can help engage users in exploration. Many online data graphics use narrative design elements to explain a given dataset in a straightforward and compelling way. According to New York Times graphic editors Mike Bostock and Shan Carter [5], these *explanatory graphics* are preferable for data-journalism, as they have the advantage of exposing up-front what the main insights from the data are, without making people "have to work for them." However, most only provide limited interactivity [24, Fig.7], which reduces the potential for personal extraction of insight.

In essence and by definition, Information visualization (Infovis) is interactive and exploratory. Thus, finding ways to make *exploratory graphics* more accessible and engaging to people is important, because if open/public/civic data is to truly empower people, then these people should be able to use appropriate tools to gain their own insights and knowledge—not only that provided by journalists in articles written or designed from a specific perspective. Here, we explore the potential of narrative visualization techniques and storytelling to trigger this desired user-engagement. By engagement, we specifically mean a user's investment in the exploration of a visualization. We present the results of three web-based field experiments, in which we compare user-behavior on a series of exploratory visualization webpages we designed that either included an initial 'story', or did not.

After the background section of this article, we describe the design of our first experiment, present our analysis of user-behavior, and discuss our results. In Section 4, we present the design of our two follow-up experiments, and discuss our results. Finally, in Section 5, we conclude with the implications of these results, and give perspectives for future work.

## BACKGROUND
One of the main purposes of Infovis is insight [18], which is usually gained through data exploration. Yet, to trigger an exploratory behavior, North suggests that users need to have initial questions; after that, they can go "beyond those initial questions in depth and unexpectedness" [18]. Exploratory behavior is related to question articulation in what Marchionini calls "information seeking" [16], where the process of question articulation, interaction with the query system, and reflective consideration of the outcome is the basis for "information tasks" [16]. An *information task* is *"the manifestation of an information seeker's problem and is what drives information seeking actions."* However, exploring an information-rich environment is rarely a single task activity, but rather a process in which each new action is the result of a set of intricate decision points derived from the previous action [25].

Toms describes this *information interaction* [25] process as a loop that cycles until a satisfactory amount of information is retrieved and integrated. According to Toms, users can initiate the interaction either by formulating a goal, or simply by deciding to examine a body of information. They then select or query a subset of this information, and scan it. When a cue is detected, they stop to examine the data, and if it is relevant, they extract and integrate it. Users can then recycle in multiple, nonlinear ways through each step.


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While these models nicely conceptualize the process of exploring an interactive-information-rich environment, they assume that users have a relatively clear initial intent or questions in mind, and that they are capable of formulating appropriate queries using the interface. However, in the context of an online exploratory visualization, where viewers may not have specific background knowledge about the data or about visualization systems, question articulation and data querying may be problematic. As such, designers and researchers [12, 15, 17, 23, 24] have suggested that storytelling can be used to trigger user-interaction and exploration, as it can provide the preliminary questions [24].

### Narrative Visualizations

Hullman & Diakoplous define narrative information visualizations as *"a style of visualization that often explores the interplay between aspects of both explorative and communicative visualization. They typically rely on a combination of persuasive, rhetorical techniques to convey an intended story to users as well as exploratory, dialectic strategies aimed at providing the user with control over the insights she gains from interaction"* [15]. This interplay raises a tension previously identified by Segel & Heer between author-driven and reader-driven scenarios [24]. *Author-driven* scenarios follow a linear structure intended by the author. In their most extreme incarnation, they provide no interaction. On the contrary, *reader-driven* scenarios give control to the person receiving the information by providing an open system, and allowing free interaction. Note that interactive narrative visualizations rarely fall directly into either of these categories, but rather somewhere along a spectrum between the two. In this article, we investigate whether author-driven scenarios can help initiate reader-driven ones.

Segel & Heer also propose a design space for narrative design elements [24, Fig.7], and identify three common structures of interactive narrative visualizations: the Martini Glass structure, the Interactive Slideshow, and the Drill-Down story. Here, we focus on the first two. The *Martini Glass* has a two-stage structure: first, the user goes through a relatively heavily author-driven scenario, in which the visualization is introduced through the use of text, annotations, nicely crafted animations, or interesting and evocative views. Second, when the author's intended narrative is complete, the user is put in charge and can actively explore the visualization following whichever path s/he considers most interesting. Thus, the authoring segment should function as a "jumping off point for the reader's interaction" [24]. The *Interactive Slideshow* structure follows a standard slideshow format, and allows for mid-narrative interaction within each slide. These may follow the Martini Glass structure by presenting the author's intended story before inviting the user to interact with the display. Thus, this structure is more balanced between the author- and reader-driven approaches.

While these frameworks are very useful for matters of design, it is still unclear whether the use of narrative visualization techniques in an introductory author-driven scenario can effectively lead to user engagement in a later more reader-driven scenario. Segel & Heer report some results of the deployment of a narrative visualization (The Minneasota Employment Explorer) [24], but the intent of the study was to create and measure social engagement in the annotation of data with personal stories, rather than personal engagement in the exploration of provided data. Although we agree with Segel & Heer that an author-driven scenario is likely to help users articulate initial questions for exploration, we question whether it is sufficient for going "beyond those initial questions in depth and unexpectedness" [18].

### User-Centered Metrics and Behavior

Measuring a user's level of engagement in the exploration of data is a complex matter, specially when it comes to online mass-media. Acquiring the necessary qualitative information is impractical, if not impossible. As such, we need to find appropriate behavioral proxies that can describe an analytical and/or exploratory intent.

Gotz & Wen have modeled patterns of user-behavior in terms of analytic actions [14]. They identify four common patterns: Scan, Flip, Swap, and Drill-Down. A *Scan pattern* describes an iterative set of inspection actions of similar data objects, and indicates a user's intent to compare attributes of these objects. A *Flip pattern* describes an iterative set of changes in filter constraints, and indicates a user's intent to compare multiple sets of the data. A *Swap pattern* describes an iterative set of rearrangements of the order in which dimensions of the data are presented, and indicates a user's intent to find correlations between various dimensions. Finally, a *Drill-Down pattern* describes an iterative set of filter operations on orthogonal dimensions of the data, and indicates a user's intent to narrow the analytic focus to a targeted subset of the data.

From a broader perspective, Rodden et al. have proposed a set of user-centered metrics for Web analytics, which they categorize in the HEART framework: Happiness, Engagement, Adoption, Retention, and Task success [21]. Some of these metrics are attitudinal and subjective, and do not fit our present needs. Others however, are behavioral and seem adequate for assessing a user's involvement with the webpage. Typically, Engagement is measured with metrics such as frequency, intensity, and depth of interaction.

While choosing appropriate metrics is essential for revealing underlying qualitative traits, these need to be related to a *goal*, and must be identifiable through different *signals* [21]. Here, our goal is to see whether augmenting exploratory information visualizations with initial narrative visualization techniques and storytelling can help engage users in exploration; we use low-level user-activity traces as signals, and we focus on analytic actions (which we refer to as *semantic operations*), and engagement—typically *depth of interaction*, which we interpret as the number of interactions a user performs that have a direct and perceivable impact on the display.

## CASE 1: THE $CO_2$ POLLUTION EXPLORER

In the rest of this article, we describe the design and results of our three field experiments. For each, we created a specific exploratory visualization webpage with two versions: one that included an introductory *narrative component*, which told a short 'story' about the topic and context of the data, provided initial insights and unanswered questions, and introduced the different visual encodings; and another that did not. Each version, which we respectively refer to as the Storytelling (ST) version and the no-ST version, was alternately assigned to new browser connections; returning connections were reassigned the same version using a Cookie. Thus, our experimental design was between-subjects.

By comparing user-behavior between versions, we seek to determine whether augmenting such a visualization with an introductory 'story' can help engage users in exploration. Our first field experiment was conducted with the $CO_2$ Pollution Explorer [1], which was first published in English on `visualizing.org`, a popular online visualization gallery, then in French on Mediapart, a popular French news and opinion outlet. The visualization was referenced as one of the "Best of the visualisation web... January 2014" on `visualisingdata.com`, and was curated in the "Visualizing Highlights: March 2014" on `visualizing.org`. It was also picked up by bloggers on `reddit.com`, `citylab.com`, various other sites, and social media. Altogether, the webpage received roughly four thousand unique browser connections between January and June 2014.

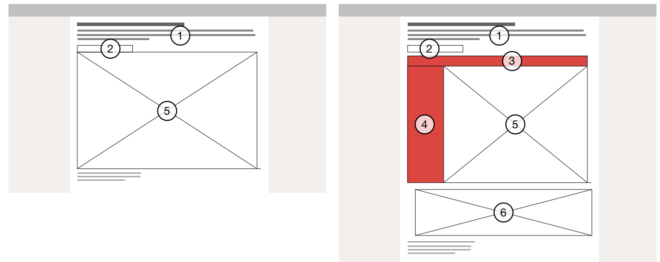
## Design

The $CO_2$ Pollution Explorer presented a dataset on the yearly evolution of $CO_2$ emissions in different countries of the OECD. The two main graphical components were a $CO_2$ Pollution Map [6], showing the emission of each country as an animated smoke cloud, and a line graph, showing the evolution of emissions over time. The narrative component in the ST version was designed as a heavily author-driven (although "user-directed") slideshow with messaging, that included five stimulating default views (or *sections*). These were sequenced using a set of stepper-buttons, which triggered various animated transitions [24, Fig.7]. Each section followed the general layout shown in Fig.1a, and interactions were limited to clicking on the stepper-buttons and hovering over the graphic—this displayed an inspector with country names and/or total $CO_2$ emissions. This design was directly inspired by many well accepted and highly acclaimed NYTimes graphics [22]. After the narrative component, the webpage 'opened up' (similarly to the Martini Glass structure) to an *Explore section*, which included only a small amount of messaging, and introduced several extra interactive features that visitors could freely use to explore the dataset. This section followed the layout shown in Fig.1b, and was what visitors assigned to the no-ST version were shown.

### *Metrics*

Using the categories of interaction described by Yi et al. [27] and inspired by Gotz & Wen's analytic actions [14], we created the following taxonomy of semantic operations users could perform with the $CO_2$ Pollution Explorer. Each level corresponds to one or several low-level interactions with specific features of the interface (presented in brackets).

- **inspect:** show the specifics of the data [*hover line graph, hover line graph dot, hover map*]
- **connect:** show related items [*hover list*]




(a) (b)

Figure 1: General layouts for sections in the narrative component (a), and for the Explore section (b). 1) short descriptive paragraph (messaging), 2) stepper-buttons (to navigate between sections—only in the ST version), 3) query-buttons, 4) list of country names and query checkboxes, 5) main graphic, and 6) secondary graphic. Additional interactive features in the Explore section are highlighted in red.

- **select:** mark something to keep track of it [*click line graph, click line graph dot, click map, click list label*]
- **filter:** show something conditionally [*click list checkbox, click "Show All Countries/Remove All Countries" button*]
- **explore:** show something else [*click query-button*]
- **narrate:** show a different section [*click stepper-button*]

To make sense of the four thousand sessions we collected, we performed some initial filtering and manipulations: 1) Since the webpage was designed for desktop browsers, we removed all mobile device connections. While displayable on such devices, the visualization offered certain interactive capabilities that touch displays do not handle (*e. g.,* hovering). In addition, mobile device displays are generally smaller than desktop ones, and we could not assert that the visualization fully fitted the screen resolution, or that if it did, it would not be too small to read and interact with. 2) While several sessions were those of returning browser connections, we considered each of them individually. Return is a good indicator for user-engagement [21]. However, analyzing aggregated sessions would have created major outliers for other metrics such as uptime or depth of interaction. In addition, while it may be conceivable that certain users opened the page, read or explored it for a moment, then turned to another activity, only to later come back and finish their exploration, our traces do not show whether users remembered what they had previously done or that they were not distracted by some external factor. In line with this, we also set a ten minute threshold for inactivity within sessions. Each session in which two consecutive traces were separated by ten or more minutes were split in two. 3) We removed all browser connections that had arrived to the webpage through social media and personal blogs. This allowed us to categorize two different visitor populations: on the one hand, we had visitors coming from visualization gallery websites, which we consider to be a *visualization-savvy population*, and on the other hand, we had visitors coming from Mediapart, which we consider to be an *information-savvy population*, but with *a priori* no particular interest in visualizations—since Mediapart very rarely publishes interactive data-graphics. 4) Finally, several of the browser connections in our traces were ours, as we had originally used the live version for debugging and demoing. Unfortunately, we had no direct method for removing these sessions, since UUIDs were random and anonymous. However, we never communicated the URL directly, and it was hard to guess or remember. Therefore, to filter out our own sessions, we removed all connections that had no previous page URL. In the end, this procedure resulted in a subset of **2975 sessions.**

To obtain practical metrics, we coded the visitor-activity traces in the following way: 1) We attributed session IDs to each returning session and computed the uptime of all sessions. We also separated out the time visitors in the ST version spent in the narrative component and the time they spent in the Explore section. 2) We counted the total amount of click and hover interactions, and extracted all *meaningful interactions*. We define *meaningful hover interactions* as *hover interactions that affect the display (e. g., an inspector overlay) and that last longer than 250ms, so that the user can perceive its effect on the display;* and *meaningful click interactions* as *click interactions that occur on interactive features of the display (i. e., not random clicks anywhere on the display).* We then added these meaningful interactions to get a *total meaningful interactions* count per session. 3) We separated out the different semantic operations, and we repeated the interactions coding procedure for the Explore section alone (in the ST version). This provided us with comparable values for identical settings in both versions. 4) Finally, we coded the sections visitors inspected in the ST version in a dichotomous way: inspected sections were coded 1 and all others 0; and we controlled for linear sequencing of these sections by looking for the pattern [1, 2, 3, 4, 5, Explore] and coding 1 when matched, and 0 otherwise.

### Hypotheses

Our analysis was driven by two qualitative hypotheses. The first was that *the narrative component should effectively immerse users in the ST version,* resulting in the fact that they should read through the whole 'story' at least once in a linear fashion, and the second, that *the presence of this narrative component should effectively engage users in the exploration of the data,* resulting in higher user-activity levels in the Explore section of the ST version than in the whole no-ST version. However, verifying such qualitative hypotheses in a web-based field experiment is impractical. Therefore, we operationalized them with the following six quantitative hypotheses:

- **H1.1 (whole webpage):** Visitors in the ST version spend more time on the webpage than those in the no-ST version,
- **H1.2 (whole webpage):** Visitors in the ST version perform more meaningful interactions with the webpage than visitors in the no-ST version,
- **H2.1 (ST version only):** A majority of visitors in the ST version inspect all six sections of the webpage,
- **H2.2 (ST version only):** A majority of visitors in the ST version inspect the six sections in a linear fashion,
- **H3.1 (Explore section only):** Visitors in the ST version spend more time in the Explore section than visitors in the no-ST version, and
- **H3.2 (Explore section only):** Visitors in the ST version perform more semantic operations in the Explore section than visitors in the no-ST version.

We conducted separate analyses for the two populations mentioned above; each was composed of three phases. First, we looked at the general differences between the ST and the no-ST versions. Then, we inspected the ways in which visitors in the ST version inspected the narrative component. Finally, we compared the ways in which visitors behaved in the Explore section between versions.

### Results

In the following subsections, we present the results for the information-savvy population (**1270** sessions). In the subsequent Discussion section, we simply report the similarities and discrepancies we found with the visualization-savvy population (**1705** sessions). With respect to the concerns and recommendations in [4, 9, 11], we base all our analyses and discussions on estimation, *i. e.,* effect sizes with confidence intervals (95% CI). Effect sizes are reported as ratios between values for the ST version and values for the no-ST version. All point estimates and 95% CI are based on 10000 percentile bootstrap replicates of the statistic applied to the data [7].

#### *Whole Web-Page Analysis*

The first part of our analysis focused on standard aggregated Web analytics (*i. e.,* total uptime and click-count). We began by inspecting the webpage's uptime in both versions. We applied a logarithmic (log) transformation to the data in an attempt to normalize their distributions. Nevertheless, the dashed histogram in Fig. 2 shows a bimodal distribution, and the one in Fig. 3 is skewed. To explain this, we looked at the day of the week and the time of the day at which visitors connected to the webpage, expecting that during working hours, sessions would be shorter. This was not the case. Pursuing, we considered that the abnormality of the distributions might be due to bouncing behaviors. The Google Analytics Help page [13] defines *bounce rate* as *the percentage of single-page visits*. While this definition is not directly applicable in our case, since we use a single dynamic page, we interpret this metric as *the percentage of visitors who perform no click interaction on the page*—since seeing different pages of a website boils down to clicking on a series of hyperlinks[1]. We emphasize that this interpretation strictly concerns the absence of click interactions, since hover interactions may be incidental.

**[step 1] 19.2%** of sessions in the ST version and **14.6%** in the no-ST version showed a bouncing behavior. The geometric mean (GM) durations of these sessions were **9.5 seconds (s)** and **17.9s**, respectively. We expected this to be the result of returning users who had already read the story and/or seen the visualization. However, the return IDs showed that **88/122** (71.9%) bounces occurred in first-time connections in the ST version, and **65/93** (70.4%) in the no-ST version.

[1] In some cases, the bounce rate is not a "negative" metric: visitors may just find the information they need on the first page without having to perform an interaction. However, in our case, the amount of information readily available on page-load is quite low.

**[step 2]** We removed all bounced sessions from further analysis, and plotted the uptime distributions again. The solid histograms in Figs. 2 and 3 show that they are now near-normal.

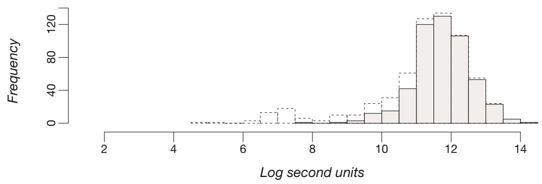



Figure 2: Log uptime distribution in the ST version.

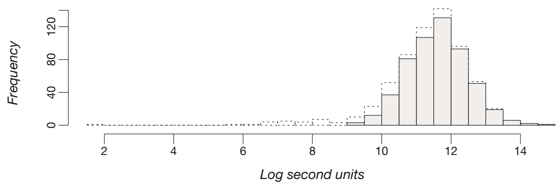



Figure 3: Log uptime distribution in the no-ST version. In both of these Figures, dashed histograms represent distributions before removal of bounced session, and solid histograms represent distributions after removal.

**[step 3]** We then compared uptime in both versions. Fig. 4 provides evidence that visitors in the ST version spent more time on the webpage (GM = **123.8s,** 95% CI [115.3, 132.9]) than visitors in the no-ST version (GM = **101.6s,** 95% CI [101.6, 117.1]), since the ratio is above 1.

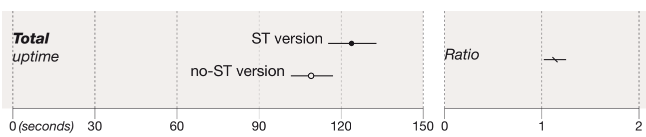



Figure 4: Geometric mean uptime with 95% CI and ratio.

**[step 4]** Next, we turned to the number of meaningful interactions. Visitors performed on average **42.7 meaningful interactions,** 95% CI [39.3, 46.3] in the ST version, and **43.7,** 95% CI [40.3, 47.3] in the no-ST version (Fig. 5). This provides no real evidence of a difference between versions.

**[step 5]** We then conducted separate comparisons of the meaningful hover and click interactions. Fig. 5 provides little evidence that visitors in the no-ST version performed more meaningful hover interactions. However, it provides good evidence that visitors in the ST version performed more meaningful click interactions.

*Narrative Framework Analysis*

The second part of our analysis focused on the narrative framework, and the way visitors in the ST version navigated through the different sections of the narrative component and the Explore section.

**[step 6]** We began by looking at the number of sections visitors had inspected. In all sessions, visitors saw more than one section; in **77.5%,** they saw the Explore section; and in **71.7%,** they saw all six sections. Similarly to the bounce rate, we expected that the sessions in which visitors did not inspect

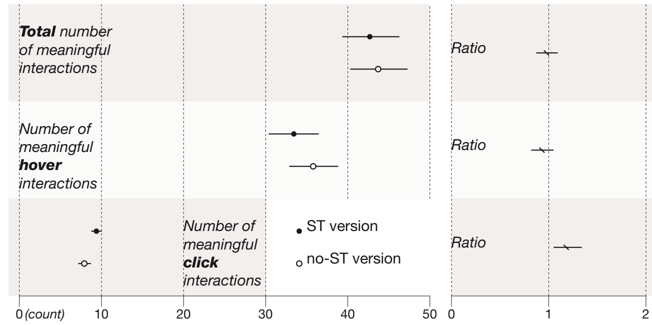



Figure 5: [steps 4 and 5] Meaningful interaction means with 95% CI and ratios for the whole webpage.

all sections would be returning visits, where visitors would have already seen some (if not all) of the content. However, the return IDs showed that **125/145** (86,2%) of these sessions were first-timers.

**[step 7]** We removed all sessions in which all six sections had not been inspected from further analysis, and turned to the number of sessions in which the narrative component and the Explore section had been inspected in a linear fashion. Only **130/367** (35.4%) met this requirement.

*Explore Section Analysis*

The last part of our analysis focused on comparing visitors' behavior in the Explore section between versions. Remember that in the no-ST version, visitors were only shown the Explore section, so the time they spent and the interactions they performed in this section are the same as those for the whole webpage [steps 1 through 5].

**[step 8]** We began by looking at the time visitors spent in the Explore section. These durations were normally distributed (once log transformed) for both versions, and their geometric means and 95% CI (Fig. 6) provide good evidence that visitors in the no-ST version spent twice as much time in Explore section as visitors in the ST version did (**108.8s**>**54s**).

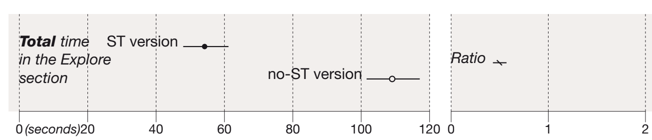



Figure 6: Geometric mean time spent in the Explore section with 95% CI and ratio.

**[step 9]** Next, we compared the amount of meaningful interactions. Fig. 7 provides good evidence that visitors in the no-ST version performed more hover and click interactions than visitors in the ST version.

**[step 10]** After that, we turned to the semantic operations visitors performed. We did not consider *narrate* operations here, as they were not available in the no-ST version. A summary is given in Fig. 8. All CI and effect sizes, except for *connect* operations, provide good evidence that visitors in the no-ST version performed more semantic operations than visitors in

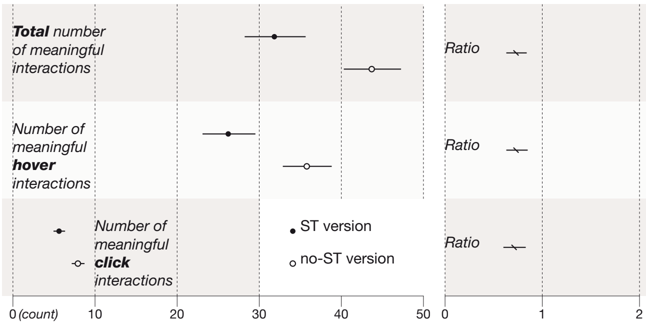



Figure 7: Meaningful interaction means with 95% CI and ratios for the Explore section alone.

the ST version. The figure also provides good evidence that in both versions, visitors mainly performed *inspect* operations. However, the most surprising finding here is that nearly no visitor at all performed *filter* operations.

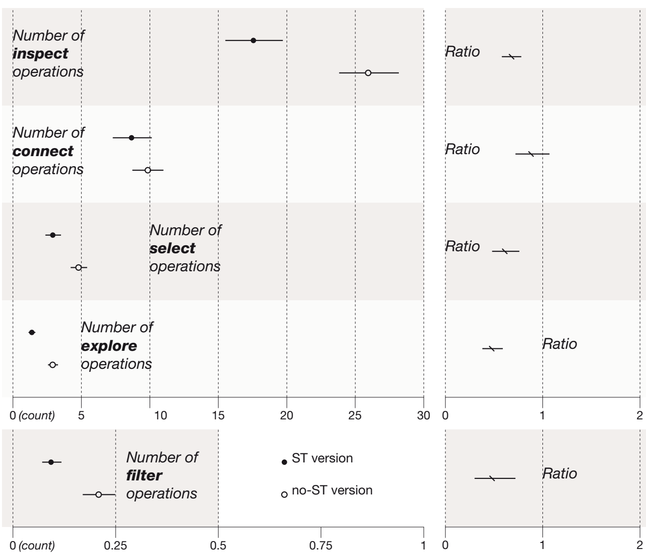



Figure 8: Semantic operation means with 95% CI and ratios for the Explore section alone. The numbers of *filter* operations are plotted with a different scale, as they are very small.

### Discussion

H1.1 is confirmed by our results [step 3]. However, the 20% bounce rate in the ST version [step 1] might indicate a certain miscomprehension of the purpose of the stepper-buttons: visitors may not have realized that it was possible to display other content. While we did not pilot-test the usability of these buttons *per se*, we did show the ST version to several people before publishing the webpage (including our editor at Mediapart), and the stepper was not an issue. Thus, another explanation, when considering the 15% bounce rate in the no-ST version and the fact that most bounces in both versions were first-time sessions, might simply be that visitors had trouble displaying the webpage; one visitor reported this, and attributed it to the browser extension Ad Block Plus (ABP).

H1.2 is only partially confirmed, as visitors in the ST version only performed more click interactions [step5]. Although these two conclusions seem rather obvious (since there was more content in the ST version), and it may be argued that on this level, the two versions are difficult to compare, this information can be valuable for a publisher, who may simply want to know what format will increase the uptime and click-count of his/her article.

H2.1 is also confirmed [step 6]. To estimate whether these visitors actually read the textual content of the narrative component, we conducted a post-hoc analysis to determine their word per minute (wpm) score. *wpm* is a standard metric for reading speed [8, p.78], and according to [20], the average French reader's score is between 200 and 250 wpm. Visitors spent roughly 78s (GM) in the narrative component, where there were altogether 269 words to read. Their average wpm is thus **207,** which makes it plausible to assume that they read the story, even if they spent extra time inspecting the graphics.

H2.2 however, is not confirmed [step 7]. This reinforces our idea of a possible miscomprehension of the purpose of the stepper-buttons. *These may not have been explicit enough to convey the idea of a linear narrative* (P1) [2].

H3.1 and H3.2 are not confirmed either [steps 8 and 10]. It should be noted however, that the interaction counts in the no-ST version are likely to include erroneous interactions, *i. e.,* interactions that visitors performed just to get used to the interface, without any specific analytical intent. Nevertheless, we consider these negligible, since the only operations that visitors in the ST version could have gotten 'used to' in the narrative component were *inspect* operations; and, even though the evidence is low, it seems visitors in the no-ST version performed altogether more hover interactions [step 5].

Overall, these results invalidate our qualitative hypotheses: the narrative component did not immerse visitors in the way we expected it to, since they did not inspect the 'story' in a linear fashion; and it did not increase visitors' engagement in exploration in the Explore section. This suggest that augmenting an exploratory visualization with initial narrative visualization techniques and storytelling does not increase user-engagement in exploration. Nevertheless, it does not mean that visitors in the ST version retrieved less information from the webpage than visitors in the no-ST version did: our results simply do not account for this. In fact, since the narrative component provided several important insights, it is possible that visitors in the ST version actually got more information out of the webpage. However, this was information we provided, not personal insight.

As visitors in both versions mainly performed *inspect* operations [step 12], it seems that the Scan pattern was predominant [14], and that visitors' main analytical intent was to simply compare the specific amounts of $CO_2$ emitted by the countries displayed by default at a single point in time. A possible explanation for this limited exploratory behavior after having inspected the narrative component in the ST version is that *visitors may have considered the information pre-*

[2] We point out possible design or usability problems uncovered by our analysis in this section, and discuss how we fixed them for our follow-up experiment in the next section.

*sented in the 'story' to be sufficient* (P2). Alternatively, it may be that *our design of the narrative component was not compelling enough to help them articulate questions about the data* (P3), and *did not sufficiently 'train' them to use the interactive features of the Explore section* (P4). It is also possible that *visitors did not perceive the dataset as being rich enough for them to spend extra time exploring it* (P5)—one visitor commented that "the graphic is interesting, but it lacks a key piece of information necessary to a political solution for the reduction of greenhouse gases: the emission rate per capita!" [1, on Mediapart]. Visitors may have indeed had too much *a priori* knowledge of the topic. A final explanation we can think of is that the visualization itself may not have been appealing enough. Toms reports that "the interface must rationally and emotionally engage the user for satisfactory resolution of the goal. [...] content alone is not sufficient" [25]. *The interactive features of the* $CO_2$ *Pollution Explorer may not have been explicit enough or may have been perceived as too limited* (P6)—as suggested by the general absence of *filter* operations [step 11].

Nevertheless, the webpage did generate some interesting debate in the Comments sections of the websites it was picked up by—typically on `citylab.com`, visitors discussed "who's responsible for cleaning up our past?", as well as possible solutions for the future, such as "a Manhattan Project for clean energy production" [1, on `citylab.com`]; but unfortunately, it is impossible to tell which version these people had seen.

Finally, while we had expected that the behavior of the visualization-savvy population would be different, specially concerning interactive-behavior, it was overall very similar; uptime was slightly shorter and interactions count smaller, but the general trends were the same—as illustrated by the ratio comparisons in Fig. 9, with the minor exception of the number of *connect* operations, for which there is good evidence here that visitors in the no-ST version performed more.

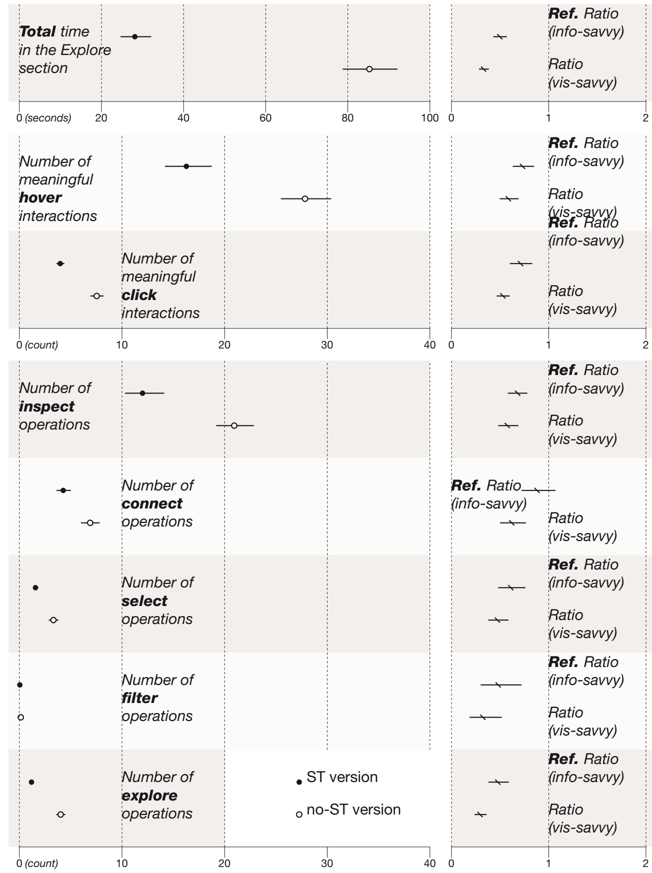



Figure 9: Activity comparisons between versions for the visualization-savvy (vis-savvy) population in the Explore section alone. Ratios for the information-savvy (info-savvy) population are also shown for reference.

## CASES 2 & 3: THE ECONOMIC RETURN ON EDUCATION EXPLORER AND THE NUCLEAR POWER GRID

To ensure these unexpected results were not confounded by the possible design or usability problems pointed out in the previous section, we conducted a follow-up study with two other exploratory visualization webpages—The Economic Return on Education Explorer [2] and the Nuclear Power Grid [3]—for which we recreated the two alternately assigned versions (ST and no-ST), thus respecting the between-subjects experimental design. In these, we attempted to solve the listed problems, which we summarize below. For each, we give a design rationale and the solution we adopted.

P1. A minority of visitors inspected the six sections in a linear fashion. **Rationale:** People should be aware that the stepper corresponds to a linear sequencing of the sections of the 'story.' **Solution:** We added a mention beneath the descriptive paragraph of the first slide to tell people that each step corresponds to a section of the 'story,' and that they can read through section using the stepper-buttons.

P2. The narrative component may have provided too many insights, which may have hindered visitors' incentive to explore the visualization. **Rationale:** To foster exploration, the 'story' should serve as a means, a "jumping-off point," not as an end. **Solution:** We told the 'story' from a specific perspective, creating a particular theme, which left more room for discovery of important insights outside of the theme.

P3. Visitors may have been unable to articulate initial questions about the data, even with the help of the narrative component. **Rationale:** People need explicit help to articulate questions if they are not familiar with the data. **Solution:** We added explicit questions in the Explore section for visitors to answer.

P4. Visitors may not have been sufficiently 'trained' to use the interactive features of the Explore section. **Rationale:** The narrative component should also provide an explicit tutorial for the visualization. **Solution:** We added a bolded instruction for each new interactive feature made available in the narrative component.

P5. The data may not have been rich enough for visitors to truly engage in exploration. **Rationale:** The dataset should hold the promise of finding interesting information for people to engage in information interaction. **Solution:** We used a richer dataset for one of the new webpages, and a simpler dataset for the other to act as a baseline.

P6. Visitors may have considered that the interactive potential of the interface was too limited. **Rationale:** People should find the interface appealing, and should be able to easily distinguish and use its different interactive features. **Solution:** On the richer dataset webpage, we added several interactive features, including direct manipulation of data objects.

We emphasize that these problems and design solutions are not necessarily new, nor are they standard. We simply point them out here, as we believed they might have confounded our previous results.

Like the $CO_2$ Pollution Explorer, we published both new webpages first in English on `visualizing.org`, then in French on Mediapart. The Economic Return on Education Explorer was soon exhibited in the "Visualizing Highlights: August 2014" on `visualizing.org`, and it received a total of roughly 1300 unique browser connections in one weekend. Unfortunately, the Nuclear Power Grid did not meet the same success; it received only 119 browser connections from Mediapart, and 131 from visualization galleries.

### Design

The Economic Return on Education Explorer (which we refer to as the *richer visualization*) used a rich dataset on the lifetime costs and benefits of investing in different levels of education in the OECD area; its main graphical component was an interactive stacked bar chart. There were four sections in the narrative component in the ST version, which followed the layout shown in Fig.1a; the Explore section followed a similar layout to Fig.1b, except it included only one graphic.

The Nuclear Power Grid (which we refer to as the *simpler visualization*) used a simple dataset on nuclear energy production and consumption in the OECD area; its main graphical component was a table in which each cell contained a numeric value, a bar chart, a pie chart, and an illustration of a cooling tower. There were three sections in the narrative component, and the layouts were again the same, except that the Explore section did not include the list (Fig.1b(4)), and query-buttons (Fig.1b(3)) were replaced by a drop-down menu.

#### *Metrics*

We created the following taxonomies of semantic operations for each visualization:

#### *Semantic Operations for the Richer Visualization*

- **inspect:** show the specifics of the data, [*hover label, hover stacked bars*]
- **filter:** show something conditionally, [*click list checkbox, click "Show All Countries/Remove All Countries" button*]
- **explore:** show something else, [*click query-button*]
- **reconfigure:** show a different arrangement, [*click stacked bars*]
- **narrate:** show a different section, [*click stepper-button*]

#### *Semantic Operations for the Simpler Visualization*

- **inspect:** show the specifics of the data, [*hover background bar, hover pie chart*]
- **reconfigure:** show a different arrangement, [*select from drop-down menu*]
- **narrate:** show a different section, [*click stepper-button*]

Since we received fewer visits for the simpler visualization, and since our previous results had shown that there was no important difference in trends between the information-savvy and the visualization-savvy populations, we aggregated the data of both populations for the two visualizations. We performed all initial filtering and coding in the exact same way as in the $CO_2$ Pollution Explorer case; in the end, we kept subsets of **1178 sessions** for the richer visualization, and of **160 sessions** for the simpler visualization. While this last number is quite small compared to those of the other cases, it is still big enough for estimation of user-behavior.

### Hypotheses

We maintained the same qualitative hypotheses as for the $CO_2$ Pollution Explorer, and thus the same quantitative hypotheses. However, the purpose of having created two new webpages was to see whether the richness of the dataset might affect the impact of the narrative component on user-engagement in exploration. Thus, we added a third qualitative hypothesis: *the impact of the narrative component on user-engagement in exploration should be more pronounced when the visualization presents a richer dataset,* resulting in higher user-activity levels in the Explore section of the richer visualization than in that of the simpler visualization.

### Results

For both webpages, we conducted the exact same analysis as before. We began by removing all bounced sessions—**27.9%** in the richer visualization case, and **33.1%** in the other—, and plotted all results of the whole webpage and Explore section analyses [steps 3 to 5 and 8 to 10] in Fig. 10. These are compared to those of the information-savvy population in the $CO_2$ Pollution Explorer case.

#### *Narrative Framework of the Richer Visualization Analysis*

**[step 6-BIS]** In **92.2%** of all sessions, visitors saw more than one section; in **57.4%,** they saw the Explore section; and in **53.7%,** they saw all five sections. The return IDs showed that **157/191** (82.2%) sessions in which visitors did not inspect all sections were first-time connections.

**[step 7-BIS]** We removed these sessions from further analysis ([steps 7-BIS to 10-BIS]). In **91/222** (40.9%) remaining sessions, visitors inspected all four sections and the Explore section in a linear fashion.

#### *Narrative Framework of the Simpler Visualization Analysis*

**[step 6-TER]** In all sessions, visitors saw more than one section; in **80%,** they saw the Explore section; and in **75.7%,** they saw all four sections. The return IDs showed that **4/17** (23.5%) sessions in which visitors did not inspect all sections were first-time connections.

**[step 7-TER]** We removed these sessions from further analysis ([steps 7-TER to 10-TER]). In **22/53** (41.5%) remaining sessions, visitors inspected all three sections and the Explore section in a linear fashion.

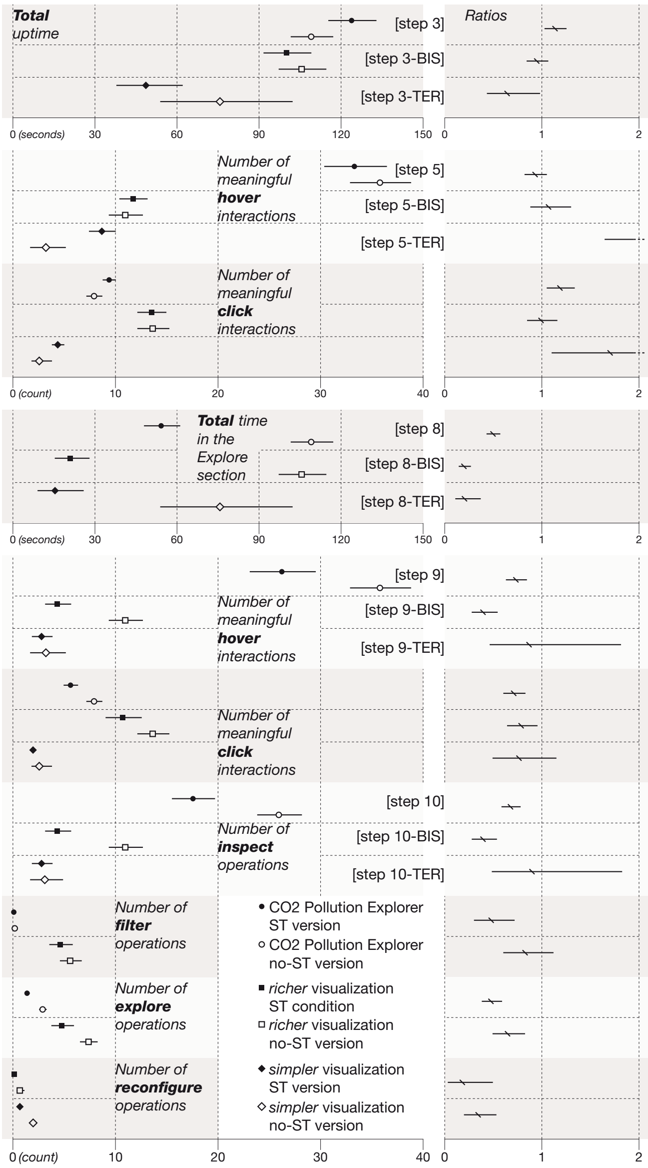



Figure 10: Activity comparisons between versions for the richer and simpler visualizations. Values for the $CO_2$ Pollution Explorer are also shown for reference.

### Discussion

In the richer visualization case, none of the 'whole webpage' and 'Explore section only' hypotheses are confirmed (H1.1, H1.2, H3.1, H3.2). In fact, there is even no evidence of a difference in total uptime, or in number of meaningful hover and click interactions between versions on the whole webpage level—as attested by the ratio 95% CI that all overlap 1 [steps 3-BIS, and 5-BIS] (Fig. 10).

In the simpler visualization case, none of the 'whole webpage' and 'Explore section only' hypotheses are confirmed either, with the exception of H1.2. However, these results are to be considered cautiously, since they show a lot of variability in the data—as attested by the very wide 95% CI. This can be attributed to the smaller sample size. Nevertheless, since we are not directly interested in effect sizes, but rather in simply seeing if there is a difference between versions, the ratio 95% CI that do not overlap 1 (Fig. 10) provide sufficient information for our needs. Overall, visitors spent the least amount of time and performed the least amount of interactions in this case, be it on the whole webpage level or in the Explore section alone—this was expected, as the dataset and interactive potential of the visualization were not as rich as in the other cases.

Finally, in both cases, H2.1 is confirmed, but H2.2 is not. While the percentages of sessions in which visitors inspected all sections of the narrative component in a linear fashion are higher than in the $CO_2$ Pollution Explorer case, they are still below 50%.

Overall, these results invalidate once again our two main qualitative hypotheses, and confirm those of the $CO_2$ Pollution Explorer: the narrative components did not immerse visitors in the way we expected them to in either cases; and they did not increase visitors' engagement in exploration in the Explore sections. Furthermore, while there is evidence that visitors of the richer visualization performed more meaningful click interactions in the Explore section than visitors of the simpler visualization did—which seems normal, since there were many more clickable features in the richer visualization; there is no real evidence that they spent more time there, or that they performed more meaningful hover interactions—as shown by the 95% CI for the analysis of the Explore sections of the ST versions in [steps 8-BIS, 8-TER, 9-BIS and 9-TER] (Fig. 10). Thus, there is no real evidence that the narrative component in the richer visualization case had a bigger effect on user-engagement in exploration than the one in the simpler visualization case—this invalidates our third qualitative hypothesis. However, from a broader perspective, confirming this third hypothesis would have been pointless, since each of our experiments have shown that including a narrative component does not increase user-engagement in exploration.

## CONCLUSION

In this article, we have shown that augmenting exploratory information visualizations with initial narrative visualization techniques and storytelling does not help engage users in exploration. Nevertheless, our results are not entirely negative. The $CO_2$ Pollution Explorer and the Economic Return on Education Explorer were successful webpages that did engage people in a certain way: both received a relatively high number of visits, and the average uptime was well-above web standards, whatever the version. They were also curated in referential online visualization galleries. Thus, beyond the spectrum of this study, it is important that the concept of engagement in Infovis be better defined. Here, we consider it from a behavioral perspective as an investment in exploration, which may lead to insight. However, engagement can also be considered from an emotional perspective as an aesthetic experience, as is done with certain *casual information visualizations* [19, 26].

Ultimately, our goal is to understand how to engage people with exploratory visualizations on the web. While this study may have failed due to the simple fact that people have a limited attention span on the internet, and that if they read through an introductory narrative component, they will not spend extra time exploring a visualization, we still claim that ‘pushing’ observations, unanswered questions, and themes from a narratorial point of view in the form of an introductory ‘story’ does not seem to encourage people to dig further for personal insights. In the future, we will continue to investigate new/other strategies for fostering exploratory behavior (like the one taken by the Game-y Infographics [10]) to allow switching from author-driven visualizations to reader-driven ones on the web.

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