

MAP-BASED VISUAL STORYTELLING:  
AN ASSESSMENT OF EMERGING GENRES AND TROPES

by  
Zihan Song

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## CHAPTER 1: OVERVIEW AND SIGNIFICANCE

### *1.1 Overview*

Storytelling is fundamental to cartography (Robinson et al., 2015). The 4<sup>th</sup> century *Classic of Mountains and Seas* told the story of mythic of Ancient China; the medieval *Beatine maps* told the story of Christian Genesis; Ogilby's *Britannia Atlas* of 1675 told the story of rising interconnectedness of British transport and trade (Brown, 1979). Historically, these spatialized stories unfolded through a set of individual, static maps (Haft, 2011). With changes in new media and web technology, map-based visual stories are both more accessible and more influential today than ever (Cairo, 2012). Further, telling stories with maps has become an increasingly important theme in cartographic research on geovisualization, volunteered geographic information, and the Geoweb, among others (Caquard, 2013). Here, *map-based visual storytelling* describes the use of a purposeful and partial sequence of maps and information graphics to advance a linear spatial story (Roth, 2015).

Increasingly, the use of maps and information graphics for visual storytelling is framed as *data journalism*: news stories supplemented and even generated by analysis and presentation of digital information (Gray, Chambers, & Bounegru, 2012). Many news organizations including the Guardian, the New York Times, and the Washington Post regularly incorporate information graphics into their news stories, a change perhaps reflecting the transition of journalism from a primarily print to a primarily digital medium. These organizations purposefully combine text, graphics, and other annotations to lead the viewer step-by-step through a linear narrative structure, telling the story from beginning to end (Segel & Heer, 2010).

While journalists have a long history of using data-driven maps as evidence in their news reports (Monmonier, 1989; Aksoy & Bayar, 2016), map-based visual storytelling arguably is

more common today than ever due to the ubiquity of *new media*, or natively-digital and web-based mechanisms for authoring and sharing information (Cartwright, 1997). Map-based visual storytelling now takes many forms in new media (Crampton, 2009) and has enabled the general public to contribute their own stories using emerging technology (Haklay, Singleton, & Parker, 2008). However, empirical research on the design of visual stories remains in its infancy both in cartography (Caquard, 2013; Roth, 2015; Cartwright & Field, 2015) and the related field of information visualization (Kosara & Mackinlay, 2013; Figueiras, 2014), resulting in few time-tested guidelines for storytelling with maps.

## ***1.2 Problem Statement and Research Questions***

There is limited empirical research on the design of map-based visual storytelling, a concern given the increased attention of visual storytelling in cartography, information visualization, and data journalism. My research contributes to three dimensions of visual story design fundamental to the success of the story, leading to three overarching research questions:

1. *Can a linear, three-act narrative be effectively applied to map-based visual storytelling?* A three-act narrative often is applied in literature and film, yet its potential for visual storytelling and data journalism is only beginning to be recognized (Smith & Watson, 2010). A traditional *three-act narrative* includes a set-up (Act 1), a conflict (Act 2), and a resolution (Act 3). Importantly, the traditional three-act narrative organizes a story in a linear manner, maintaining a consistent sequence across story elements as the plot unfolds. In this research, I designed two map-based visual stories using a *three-act narrative* structure.

2. *What is the influence of visual storytelling genres on the retention, comprehension, and preference of the story?* A visual storytelling genre describes the structural and stylistic elements that separate a form of story (or other artwork) from others (Roth, 2016). As reviewed in Chapter 2, Segel and Heer (2010) offered a taxonomy of seven visual storytelling genres, which has been revised by Roth (2016) for the specific application of map-based visual storytelling. In this research, I examined differences in story comprehension, preference, and retention between two specific visual storytelling genres: *longform infographics* and *dynamic slideshows*.
3. *What is the influence of visual storytelling tropes on retention, comprehension, and preference of the story?* A visual storytelling *trope* describes a literary or rhetorical device used to advance a story, much like a figure of speech in literature (Roth, 2016). I examined one important trope used in visual storytelling: *focus attention*, or design elements that attract the reader's attention to important elements of the story (Gershon & Page, 2001). I investigated the impact of two focus attention strategies commonly used in cartography and information visualization (Robinson, 2011): *color highlighting* and *leader lines*. I provide additional background on genres and tropes in Chapter 2.
4. *What is the influence of individual differences of the reader on retention, comprehension, and preference of the story?* Multiple personal characteristics can influence retention, comprehension, and preference—and therefore the success—of a visual story design. Designers must consider ability, expertise, and motivation during map design (Roth, 2013). Because this research addresses the use of maps in complex stories of timely, sometimes controversial events, prior beliefs about the story topic

also were considered to determine if and to what degree visual stories may cause readers to shift their perspectives.

I administered an online map survey with a 2x2x2 factorial design to address the above research questions. I designed two map-based visual stories using a traditional three-act narrative: a first on U.S. *sea-level rise* and a second on U.S. *presidential campaign donations*. I then modified each story systematically to produce versions in two genres (*longform infographics*, *dynamic slideshows*) and two focus attention strategies (*color highlighting* and *leader lines*), resulting in a total of eight different designs. Each design was evaluated by retention, comprehension, and preference, taking into account a range of factors regarding individual different.

Compared to its increasing popularity, research in map-based visual storytelling is comparatively rare. This study filled this important gap in the cartography by examining the utility of a three-act narrative for map-based visual storytelling. It also is the first study to explicitly assess emerging visual storytelling genres and tropes. As discussed in Chapters 4 and 5, envisioning cartographic design as visual storytelling provided useful, as the three-act narrative generally was a successful approach for packaging the information, yet not all visual storytelling designs performed equally. Visual storytelling *design matters*.

This thesis proceeds with four additional chapters. In Chapter 2, background on the topics of map-based visual storytelling and narrative structure are provided, as well as an overview of genres and tropes. The story design protocol and analysis procedure are described in Chapter 3. Results of the online survey study are presented in Chapter 4. Final thoughts on and future directions for research on map-based visual storytelling are provided in Chapter 5.

## CHAPTER 2: LITERATURE REVIEW

### *2.1 Visual Storytelling, Cartography, and Data Journalism*

Although relatively limited empirical research has been conducted on map-based storytelling in cartography over the past 50 years (see Monmonier, 1989, for one example), the terms “story map” and “spatial narrative” have become buzzwords in professional cartography. Today, *map-based visual stories* are tools for providing an explicit, spatial, and visual complement to the implicit geographic components of a textual story or argument (Caquard & Cartwright, 2014). Further, there is growing interest in exploring the relationship between maps and stories beyond public communication: maps are becoming a visual tool to express the geographic dimension of personal experiences (Sparke, 1998; Caquard, 2013; Pearce, 2008).

This upward trend in map-based visual stories perhaps is part of the rise in data journalism introduced in Chapter 1 (Cairo, 2012). Data journalism is an iterative process that includes collecting disparate data, analyzing and filtering the collected data, visualizing the data, and ultimately forming a story that hinges upon key insights in the data (Weber & Rall, 2012; Rogers, 2014). Thus, the data journalism process is much like the highly iterative process we follow in cartographic design: both journalist and cartographer are active in shaping an explanation of the provided graphics, images, and text (Muehlenhaus, 2013). Vujaković (2014) characterized the kind of themes receptive to map-based visual, ranging from environmental issues to politics (Table 2.1). Nearly any story lends itself to map-based visual storytelling, as all events occur in spatial or geographic contexts.

Themes	Sub-themes
A. Politics: Internal	1. Government, legislation, electoral, parties, non-violent protest/ strikes 2. Riots, terrorism, civil conflict/ war, secession movements, coupes
B. Politics: International	3. International relations, negotiations, agreements (non- trade) 4. Military conflict/ war, defense issues, territorial/ resource disputes
C. Disasters/ Accidents	5. Large-scale disasters, (earthquakes, floods, etc.), epidemics 6. Accidents (transport, etc.), explosions & fires, industrial disasters, weather problems (e.g. avalanche)
D. Environment and Science	7. General science, natural science, engineering, medical 8. Environmental problems/ impacts, pollution 9. Transportation systems, development and planning 10. Land use/ resource planning & conservation, public works, neighborhoods
E. Society	11. Demography/ social trend, housing, employment, education 12. Crime, courts/judicial, police, missing persons 13. Social disasters (famine, refugees)
F. Cultural affairs	14. History & archaeology, heritage, the art and “media” 15. Travel, tourism, recreation and sport 16. Human interest/ ‘odd events’, religion, VIPs/ Royals, scandals (non-political), minor accidents (few people)
G. Economics	17. Business & finance, industry 18. Macro-economics, trade agreements, international, monetary issues, aid and economic development

**Table 2.1: Vujaković’s (2014) Survey of Map-based Visual Stories.** The research reported here draws examples from A. Politics: Internal, and D. Environment and Science.

## 2.2 The Three-Act Narrative (RQ #1)

The concepts of “narrative” and “story” are not the same. *Narrative* describes the structuring of story elements—organized into a sequence of frames or panels in a visual narrative—while *story* is the addition of unique content to a particular narrative structure (Gershon & Page, 2001; Segel & Heer, 2010). Convention in literature and film has led to a widely recognizable *three-act narrative* commonly applied to structure a story (Smith & Watson, 2010):

*Act 1:* The narrative begins with a *set-up* act introducing the setting, key characters, and problem context. The *setting* provides basic information for building an overall scene for the audience, putting them in a specific time, place, and social context. The set-up also often

includes a *hook*, or an exciting early scene that captures the attention of the audience and encourages them to continue reading. Next, *key characters* who act out the narrative are introduced, and may include *protagonists*, the leading or hero characters, and *antagonists*, the opposing or anti-hero characters who contend with the protagonists or represent an alternative point of view. Finally, the set-up provides other information about the *problem context* that later will be necessary the audience to understand the unfolding narrative.

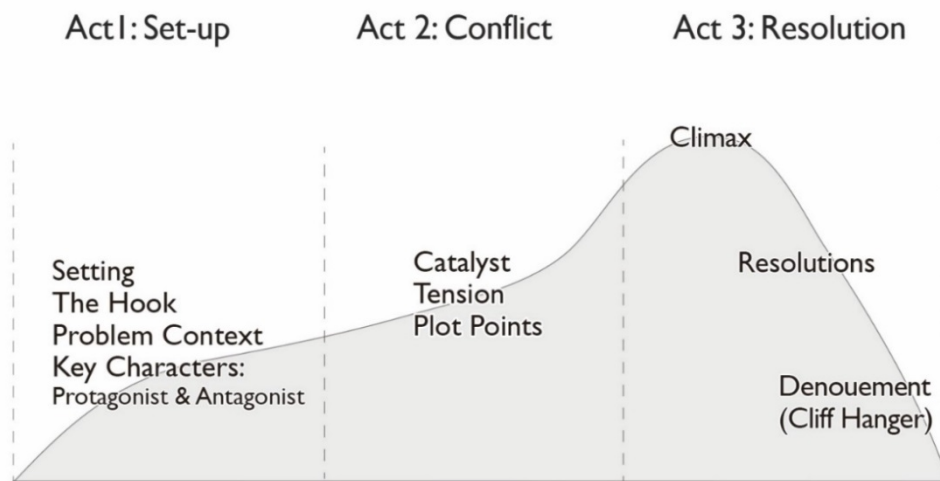
*Act 2:* The narrative then progresses into the *conflict* act, which first intervenes with the *catalyst*, or key issue driving the story, and then slowly builds suspense through rising plot points. The conflict often is the most important and the longest act in a story. The catalyst produces a *tension* among characters, particularly between the protagonist and antagonist. The characters and setting introduced in the set-up then respond to this tension through a series of *plot points*, which provide the audience with new information about the problem to develop the narrative, add tension, and build suspense. The characters react and evolve at each plot point, and this *character development* humanizes the story and its characters for the audience.

*Act 3:* The narrative concludes with the *resolution* act, where the narrative arc culminates in a final confrontation and characters suggest and even choose among competing solutions to the problem starting the conflict act. The resolution contains the dramatic *climax* of the narrative, or final plot point facing the protagonists and antagonists, bringing their character arcs together. Following the climax, characters again return to their own paths (some may be discontinued), representing different solutions to the problem. The resolution concludes with the *denouement* in which remaining matters are explained or resolved, or several narrative elements are left for the audience to determine in a *cliffhanger*, stimulating their imagination and curiosity while allowing



the audience to “fill the gaps” using their own experiences and predictions (Gershon and Page, 2001: 35).

In this way, map-based visual stories covering very different themes (e.g., Table 2.1) can share similarities in their design if using the same narrative structure. Figure 2.1 illustrates the conventional three-act narrative and its components for visual reference (Young, 2012). Phillips (2012) describes eight ways that explicitly geographic characters can evolve during a traditional three-act narrative: cause and effect, convergence, divergence, oscillation, destruction, genesis, emergence, and metamorphosis. While numerous visual and cinematic storytelling deviates from this traditional narrative substantially (Muehlenhaus, 2014), the research reported here consistently applies the three-arc narrative to understand its utility for map-based visual storytelling.

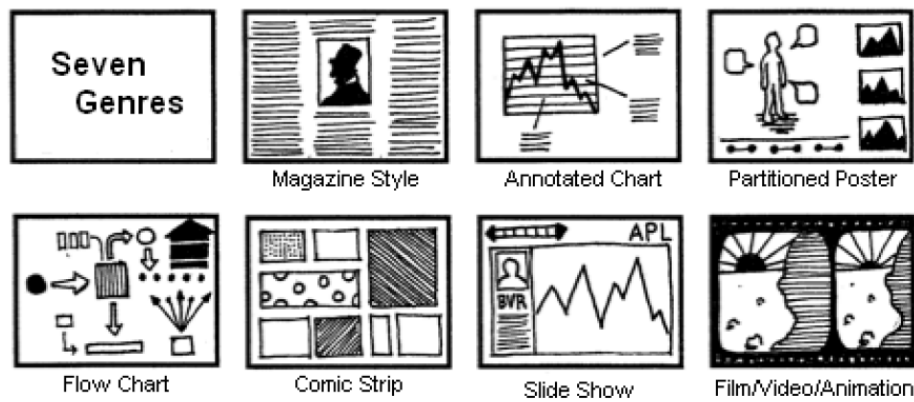


**Figure 2.1:** *The Traditional Three-Act Narrative after Young (2012).*

### **2.3 Visual Storytelling Genres (RQ #2)**

As introduced in Chapter 1, *genres* are categories of map-based visual story designs based on coherent stylistic criteria. Segel and Heer (2010) propose seven basic genres of visual

storytelling unspecific to cartography: magazine style, annotated chart, partitioned poster, flow chart, comic strip, slide show, and film/video/animation (Figure 2.2, Table 2.2). This seven-part classification of genres is based primarily on the number of different elements or frames within the story, and the ordering of these elements in the visual presentation. Segel and Heer (2010) imagine the ability to mashup combinations of these genres, and to supplement each with interactive and dynamic content.



**Figure 2.2: Visual Storytelling Genres.** The Segel and Heer (2010) taxonomy of visual storytelling genres largely focus on newspaper, magazine, or printed static material.

Genres	Definition
<i>magazine style</i>	an image embedded in a page of text
<i>annotated chart</i>	a chart with additional doses of information provided as annotations
<i>partitioned poster</i>	a multi-view visualization with a loose order to its images, photos, and other elements
<i>flow chart</i>	a diagram that represents the steps in a process with boxes of various shapes and their order with connecting directional arrows
<i>comic strip</i>	a sequence of images arranged in interrelated panels to form a story that follows a strict linear path
<i>slide show</i>	a linear structure incorporating interaction mid-narrative within the confines of each slide, allowing the user to further explore particular points of the presentation
<i>film/video/animation</i>	a series of rapidly changing static images

**Table 2.2: The Segel and Heer (2010)'s Taxonomy of Visual Storytelling Genres**

However, Kosara and Mackinlay (2013) argue that the majority of the genres proposed by Segel and Heer (2010) are influenced by and therefore primarily limited to printed newspaper stories, and the film/video/animation genre including dynamic content is influenced primarily by passive television news reporting and not emerging forms of new media dominating trends in data journalism and visual storytelling today.

In response, Roth (2016) proposes a new taxonomy of visual storytelling genres specific to digital mapping that includes six genres: news maps (encapsulating most design for static or print mapping listed by Segal & Heer, 2010), longform infographics, dynamic slideshows, narrated animations, personalized story maps, and multimedia experiences (Table 2.3). Rather than basing the classification on the number of elements or frames, the Roth taxonomy distinguishes each genre on the manner that graphics are presented to structure a linear, three-act narrative (additional details on linearity in the next section). For example, dynamic slideshows enforce linearity interactively by requiring the reader to click through each story frame, while longform infographics enforce linearity through reader scrolling of the browser window. Both strategies impose linearity in the way that the visual story is read. Thus, the Roth taxonomy directly relates to the description of narrative introduced above, outlining different visual solutions for encoding a three-act (or other) narrative arc.

Genre	Definition
<i>Static news maps</i>	linearity enforced by layout, highlighting, and annotation on the map
<i>Longform infographics</i>	linearity enforced through the browser window's scroll functionality
<i>Dynamic slideshows</i>	linearity enforced clicking or swiping through panels presented individually
<i>Narrated animations</i>	linearity enforced by the narration and advancement of time in the animation
<i>Personalized story maps</i>	linearity enforced by the user
<i>Multimedia experiences</i>	linearity enforced through the layout and hyperlinking of text, images, and graphics

**Table 2.3: The Roth (2016) Taxonomy of Map-based Visual Storytelling Genres**

## 2.4 Visual Storytelling Tropes (RQ #3)

As mentioned above, genres can be classified based on their sequential narrative structure, or their manner of enforcing linearity. A *trope* is a rhetorical device used to advance a narrative arc, with linearity being only one such trope (Roth, 2016). Drawing on Gershon and Page (2001), Roth identifies seven tropes that can be used in map-based visual storytelling.

1. *Setting the mood* describes establishing and maintaining a visual tone congruent with the setting, characters, and problem context. Some commonly manipulated design dimensions for setting a mood include layout, linework form, color palette, and typography, each of which lead the audience to approach the visual story from a specific emotive perspective (Muehlenhaus, 2014). The Figure 2.3 example from the *Atlantic* evocatively sets the mood before launching the narrative arc of the visual story. This longform infographics use black color and a dark tone for setting an ominous, guarded mood at the beginning of the story. Setting the mood quickly alerts the audience to the story theme and intrigues their curiosity.

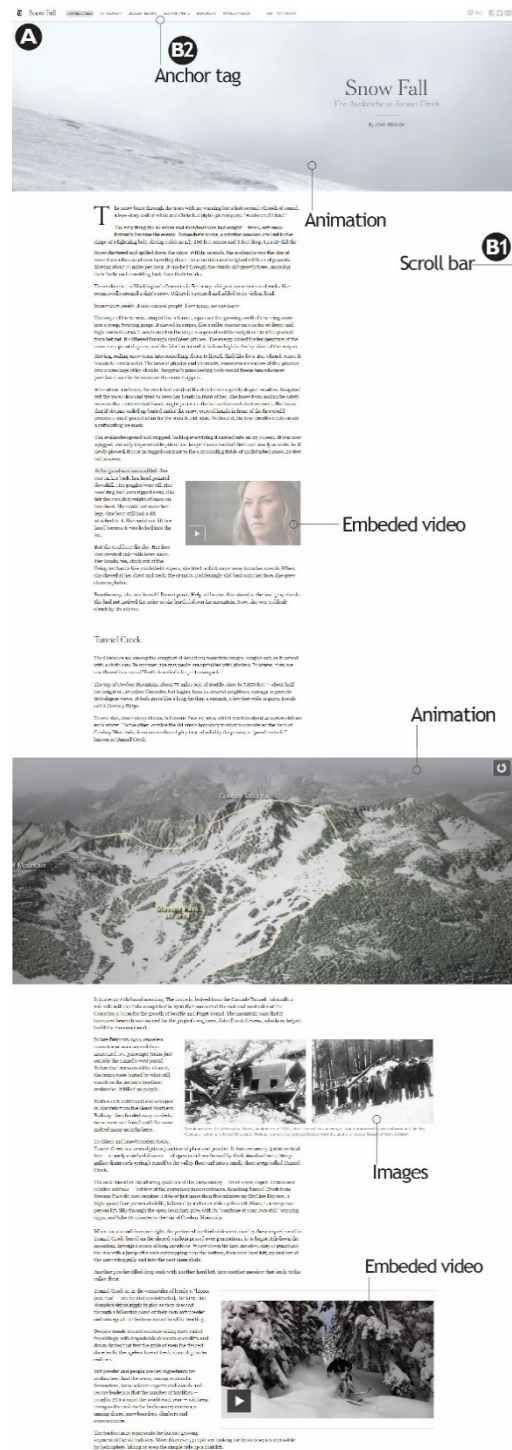
2. *Enforcing linearity* establishes a specific order for reading story content. As introduced above, Roth (2016) argues that the solution for enforcing linearity is the primary way that visual storytelling genres should be delineated. The Figure 2.4 example from the *New York Times* is a multimedia visual experience, enforcing linearity using vertical browser scrolling as well as hyperlinks and anchor tags to activate text descriptions, images and graphics, and video and animated content in a planned order, resulting in a rich and linear multimedia experience.

3. *Information dosing* reduces visual complexity by packaging content into a set of immediately understandable chunks of information. The Figure 2.5 example from *National Geographic* doses information across panels in a dynamic slideshow. As the user advances panels in the slideshow, the map is updated or zoomed, with the information panel on the right

updating to provide new story content. Such information dosing splits the story into several “bite-sized” portions to improve comprehension and retention.



**Figure 2.3: Setting the Mood in Prison/Princeton.** (A) *Genre*: The example makes use of a longform infographic to tell the story of comparison between costs in college and prison. (B) *Tropes*: The beginning of the visual story uses bold colors and a large title to draw the audience’s attention and engage their interests. The dark color palette reinforces the “prison” theme and the coarse background texture sets a dark and serious tone for the story. Source: The Atlantic (2011).



**Figure 2.4: Enforcing Linearity in Snow Fall (partial).** (A) *Genre*: This multimedia experience uses images, animations, and videos to tell the story of skiers and snowboarders' experiences during an avalanche. (B) *Tropes*: The scroll bar (B1) combined with anchor tags (B2) enforce a linear narrative structure. Source: Branch et al. (2012).

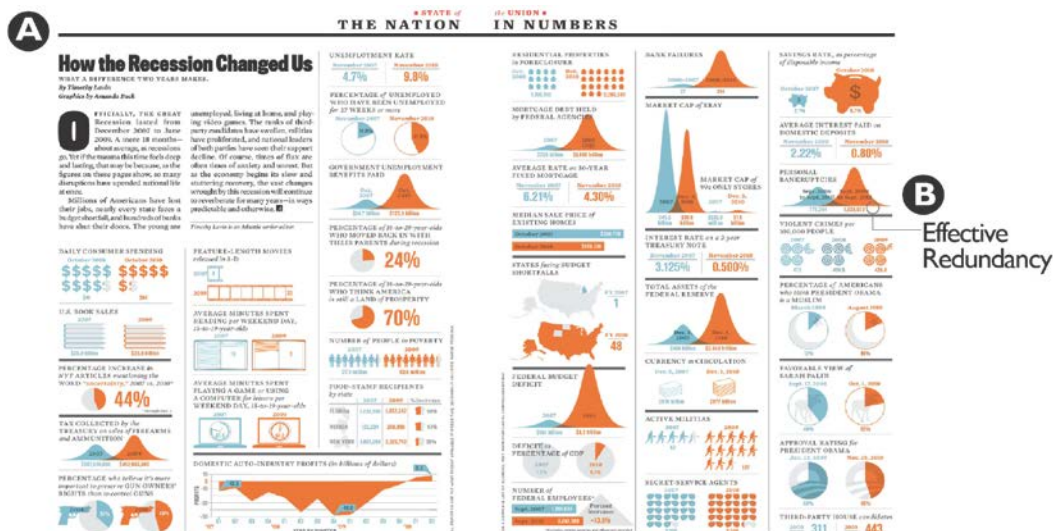
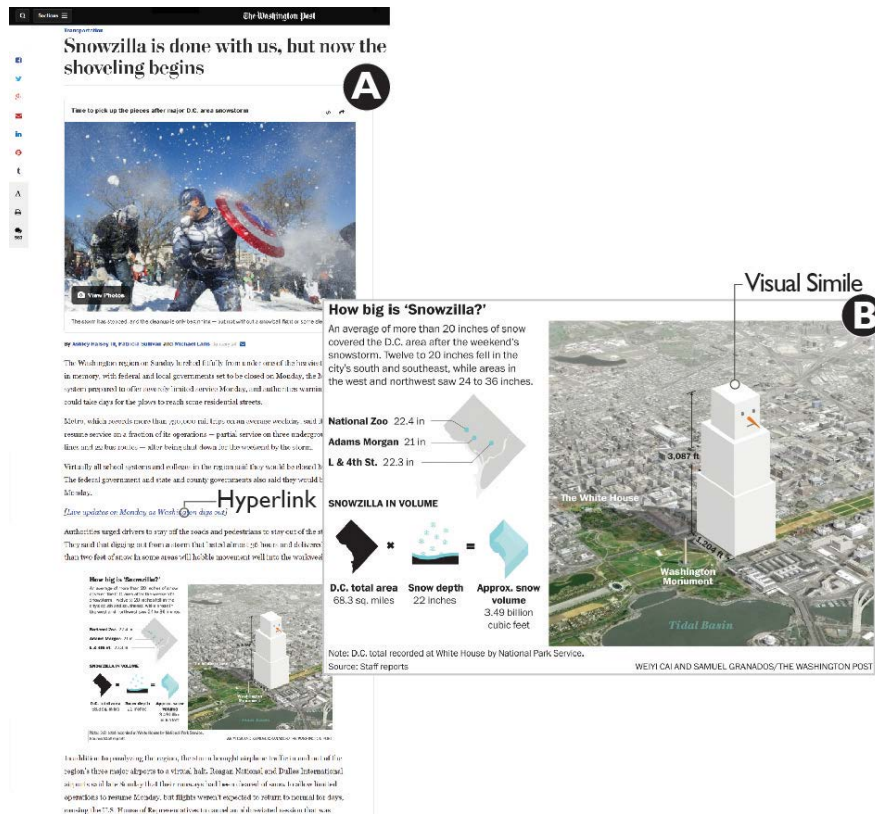


**Figure 2.5: Information Dosing in Amazonia under Threat (partial).** (A) *Genre:* These dynamic slideshows use previous and next buttons (the < and > controls) to advance the linearly through multiple threats to the Amazon. (B) *Tropes:* Each slide contains a single dose of information, such as a small amount of text or a graphic, pairing this information dosage with a dynamically zoomed central map. Source: National Geographic (2015)

4. *Visual simile* derives or synthesizes new information to facilitate understanding of original information. Some techniques include benchmarking, cartooning, and hyperrealism. The Figure 2.6 example from the *Washington Post* uses a fictional cartoon depiction of a snowperson to build a visual benchmark about the magnitude of the snow storm in the D.C. area, leaving a direct impression on the audience through visual simile.

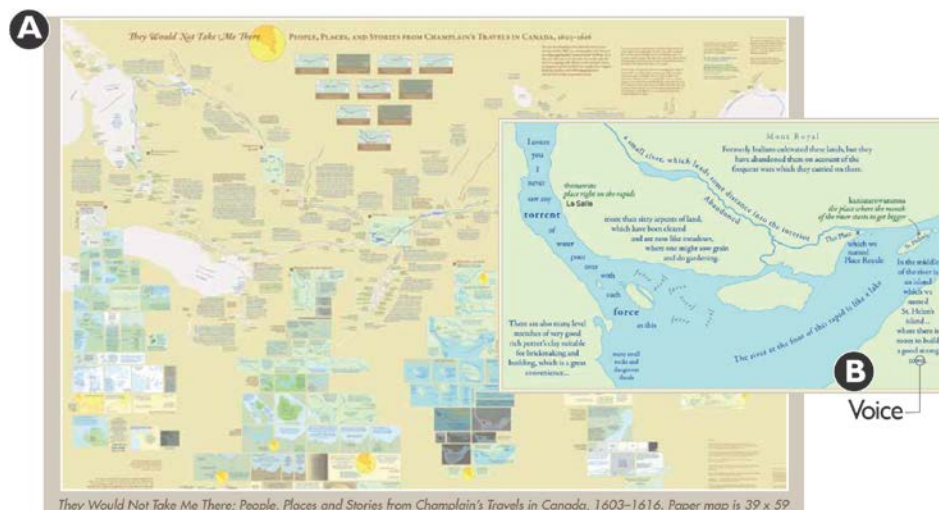
5. *Effective Redundancy* repeats important or unusual information to develop and reinforce story themes. For visual storytelling, effective redundancy may repeat colors or symbols to develop *visual motifs*, or recurring visual elements example in the storyline. The Figure 2.7 example from *the Atlantic* repeats blue and orange colors to represent two different time stamps, leaving a deep impression on the user about the story tension between before and after the Great Recession.





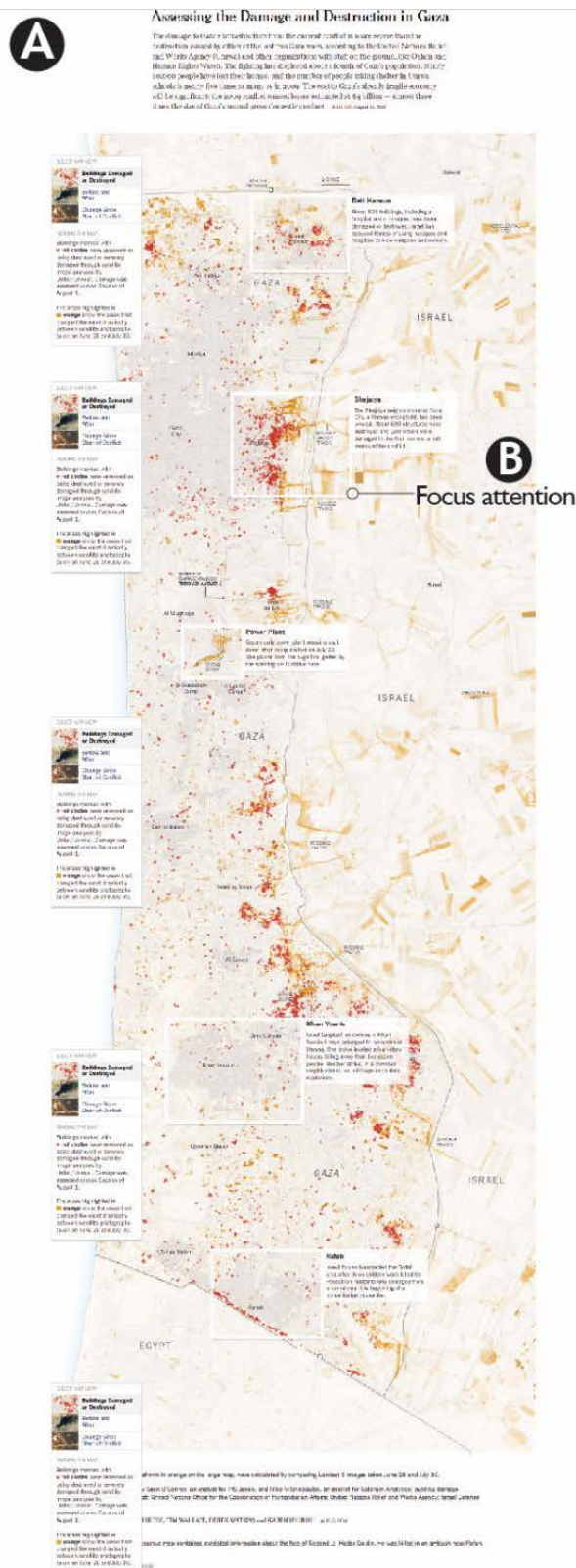


6. *Voice* interjects subjective, character-driven, or audience-driven statements and reflections into the visual story. Voice personalizes and humanizes a story, allowing both designers and the audience to draw from their experiences, opinions, and values when interpreting the story. The Figure 2.8 example from Pearce and Herrmann (2013) illustrates the eighteenth century historical landscape of Samuel de Champlain in the Upper Great Lakes fur trade. The story is told in three voices: Champlain's, the indigenous people already in the area, and the cartographers', a rich use of different voices to complicate the characters and build tension in the visual story.



**Figure 2.8: Voice in They Would Not Take Me There; People, Places, and Stories from Champlain's Travels in Canada, 1603-1616.** (A) *Genre*: This personalized story map tells the story of Champlain's travels in Canada. (B) *Tropes*: The story applies various voices to embed personal experiences and emotions. Source: Pearce and Hermann (2013).

7. *Focus Attention* emphasizes important or unusual information that cannot be missed in the story. The Figure 2.9 example from the *New York Times* uses thick, white frame annotations and adjacent call-outs to draw the attention of the audience to destroyed buildings at specific sites, as these locations received the most extreme damage from the conflict in the Gaza Strip.



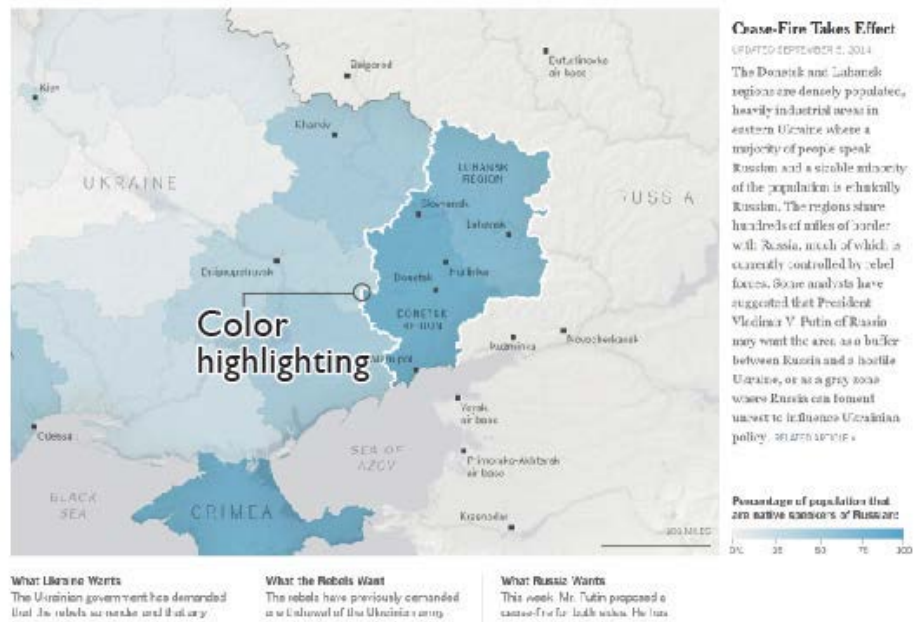
**Figure 2.9: Focus attention in Assessing the Damage and Destruction in Gaza. (A) Genre:** This example uses a single map as a longform infographic. **(B) Tropes:** This story uses white frame annotations and adjacent call-outs to draw audience's attention to the essential parts of the story. Source: New York Times (2014b)

In the research reported here, I explored the influence of different strategies to enforce linearity (summarized as genres above) and focus attention. Regarding the latter, focus attention describes a range of design solutions that produce an “Isolation Effect”, making one item stand out over others in a visual scene (Lidwell, Holden, & Butler, 2010: 254-255). Some commonly used techniques for focus attention in visual storytelling include annotation, highlighting, masking, call-outs, and dynamic zooming, as described by Roth (2016) (Table 2.4). The Figure 2.10 and 2.11 examples from the *New York Times* and *BBC Online*, respectively, compare the implementation of focus attention using color-based highlighting versus call-outs connected with leader lines.

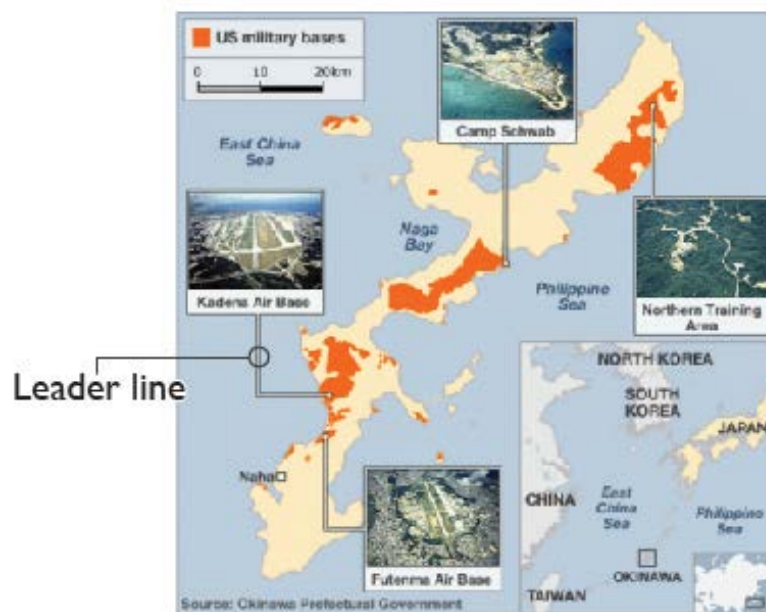
While focus attention and highlighting are active research topics in exploratory geovisualization (e.g., Robinson 2011; Griffin & Robinson, 2015), focus attention has been examined as a design trope for map-based visual storytelling. In my study, I examine the influence of two design strategies for focus attention: *color highlighting* and *leader lines* (Table 2.4).

Focus attention strategies	Definition
<i>Masking</i>	placing opacity masks over features that are not of interest to focus on map features of interest
<i>Call-outs</i>	providing supplementary labels, graphics, or images anchored to map features of interest with a leader lines
<i>Annotations</i>	adding annotations atop the map to provide details about story elements
<i>Highlighting</i>	adjusting the symbolization to attract the user’s attention to a portion of the visualization
<i>Dynamic zooming</i>	zooming to a specific portion of the map based on the story advancement

**Table 2.4: Focus Attention Strategies (Roth, 2016).**



**Figure 2.10: Using Color highlighting to Focus Attention: Cease-Fire Takes Effect.** This story uses a white outline to highlight a contested region between Russia and Ukraine. Source: New York Times (2014a)



**Figure 2.11: Using Leader lines to Focus Attention: US Base Opponent Wins Okinawa Governor Poll.** This visual story uses leader lines to give supplementary explanations of key US military bases in Okinawa. Original source: BBC News (2014).

## 2.5 Visual Storytelling and Individual Differences (RQ #4)

A number of variables affect an individual reaction to a story (Denil, 2011). The representation paradigm shows that a map is imbued with multiple layers of meaning (MacEachren, 1994), and the interpretation of these meanings are influenced by users' experiences, beliefs, and values (Wood 1992).

Therefore, in addition to design considerations, *individual differences* may be essential factors influencing the retention, comprehension, and preference of map-based visual stories. Individual user differences can cause variations in the performance of completing a given map reading task. Possible individual difference factors include expertise, culture, gender, age, and sensory disabilities (Slocum et al., 2001). In this study, the same map-based visual story may have a different effect on different readers, as their understandings of the stories are framed by their experiences, expectations, and personal interests. Potentially relevant reader characteristics to the success of a visual story include the dimensions of expertise, motivation, and ability commonly that are addressed in interactive cartography (Roth, 2013), as well as personal beliefs about the story topic.

*Expertise* describes the importance of learned knowledge and skills to enhance and extend one's innate abilities. Expertise for data journalism includes the amount of formal education or training on the story theme, the amount of professional experience with the story theme, and the self-reported degree of familiarity with the story theme. Further, expertise for map-based visual storytelling also includes these dimensions of education, experience, and familiarity with map and graphics, as well as new media and computing technology (Roth, 2013).

*Motivation* is the desire one has to read a story either out of necessity or out of interest, and can have considerable impact on comprehension and retention of the story theme (Roth & Harrower, 2008; Roth, 2013). It is unusual to find a story that worked equally well with readers of all level of motivation, which suggests the need for research on how best to design map-based visual stories that will be accessed by general public as well as domain enthusiasts.

*Ability* also can have considerable impact on map-based visual stories reading. This influential factor emphasizes the perceptual and cognitive limits of the average reader. Potential visual impairments include non-sightedness, color vision deficiency, and corrected vision.

Finally, *personal beliefs* are complex and qualitative influences developed from prior experience that may bias a reader in favor for or against a contentious position. Regarding map-based visual stories, prior personal beliefs may persistent even in the face of evidence that invalidates them (Cohen, 2012).

## CHAPTER 3: METHODS

### *3.1 Participants*

A total of 125 participants completed an online survey to assess the variation in retention, comprehension, and preference across different map-based visual story designs. Participants were recruited from Amazon Mechanical Turk to capture diversity in age, gender, education levels, and personal beliefs. Four participants piloted the survey in a controlled environment in the University of Wisconsin Cartography Lab to capture potential effects of the online testing environment and identify any potential issues with the survey design. Small errors in text and styling were fixed after the pilot study, but no major changes were made to the study design.

Participants completed the survey on their own computing devices and were instructed to use non-mobile devices (e.g., desktop or laptop computers) only. Because all evaluated map-based visual stories dealt with U.S. based issues (see below), participation was limited to the general U.S. public. Participants received \$4 for completing the survey, with the survey taking on average 35 minutes to complete. Figure 3.1 provides a breakdown of the participant sample. Measures included overall demographics information, ability, education, expertise, familiarity, motivation, and beliefs/bias.

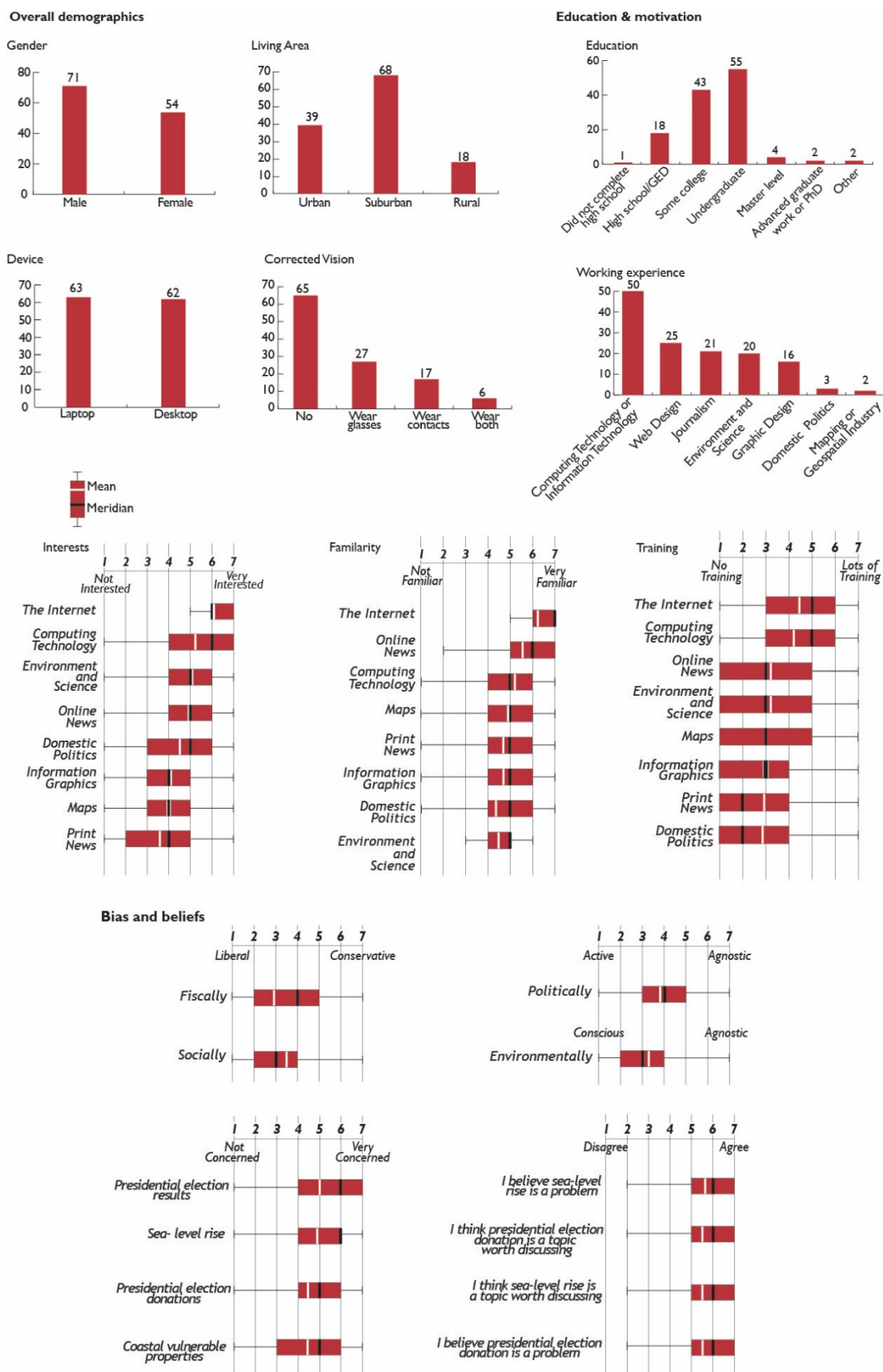


Figure 3.1: Participants' Background Characteristics.



### 3.2 Materials

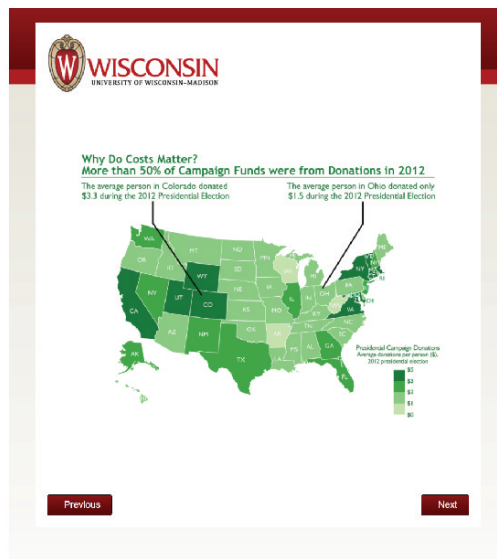
The online experiment followed a 2x2x2 factorial design (Montello and Sutton, 2013) using the Qualtrics online survey tool (Figure 3.):

- Factor #1: *Theme*. Conditions include stories on *U.S. sea-level rise* and *U.S. presidential campaign donations*. These conditions exemplify the “Politics, Internal” versus the “Environment and Science” themes outlined in Vujaković’s (2014). Both conditions followed a three-act narrative structure.
- Factor #2: *Genre*. Conditions include the *longform infographics* and the *dynamic slideshow*, two of Roth’s (2016) six map-based visual storytelling genres;
- Factor #3: *Tropes*. Conditions include two common design solutions for focus attention, *color highlighting*, and *leader lines*. I used black for *color highlighting*, as black was not used for symbolization and therefore could be applied consistently across the graphics. Use of black also did not suffer from potential issues with color vision deficiency.

Story	Theme (Factor #1)	Genre (Factor #2)	Trope (Factor #3)	Appendix
Story 1	Sea- level rise	Longform Infographics	Color highlighting	A
Story 2	Presidential Campaign Donations	Longform Infographics	Leader lines	B
Story 3	Presidential Campaign Donations	Longform Infographics	Color highlighting	C
Story 4	Sea- level rise	Longform Infographics	Leader lines	D
Story 5	Presidential Campaign Donations	Slideshows	Leader lines	B
Story 6	Sea- level rise	Slideshows	Color highlighting	A
Story 7	Sea- level rise	Slideshows	Leader lines	D
Story 8	Presidential Campaign Donations	Slideshows	Color highlighting	C

**Table 3.1: The 2x2x2 Experimental Design Resulting in Eight Unique Map-based Visual Stories.**

The 2x2x2 factorial design resulted in eight unique stories (Table 3.1), with four different visual storytelling designs: two on U.S. *sea-level rise* (Appendices A and D) and two on U.S. *presidential campaign donations* (Appendices B and C).



(a)Dynamic slideshows

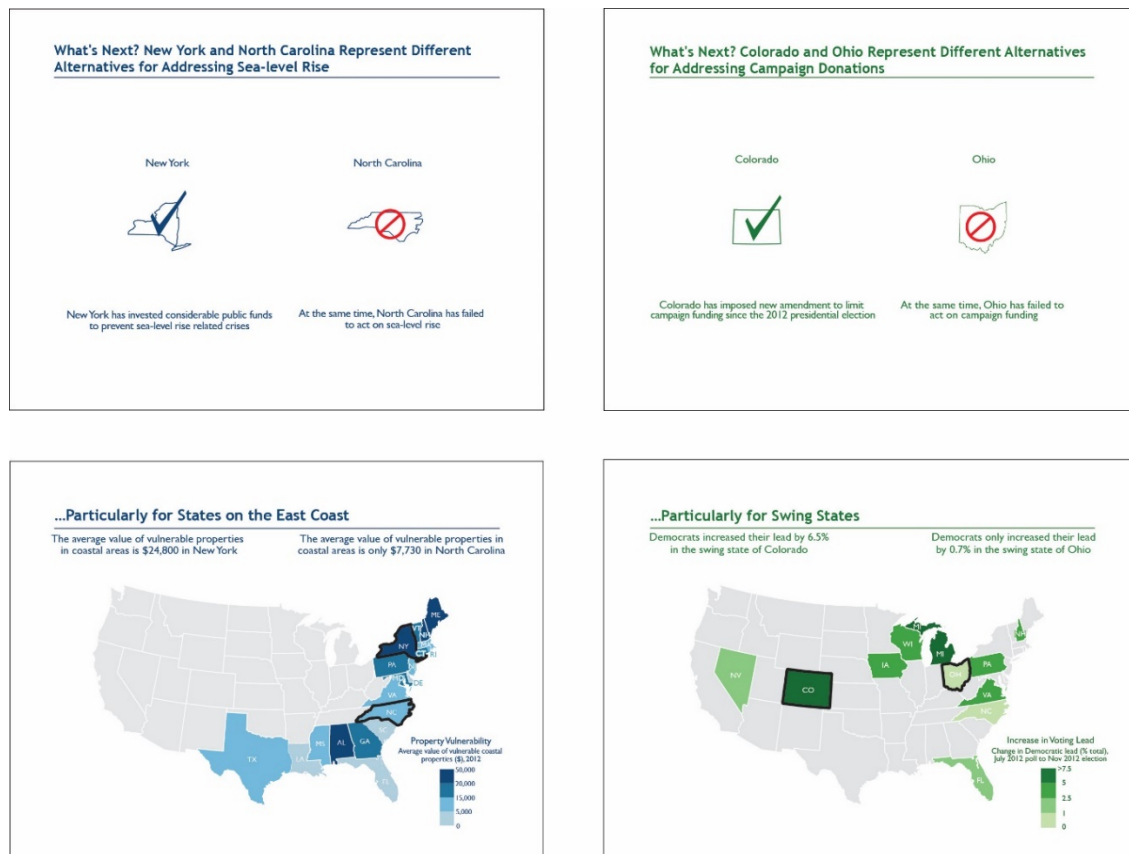
(b)Preferences questions

(c)Retention tasks

(d)Exit survey

**Figure 3.2: Qualtrics Interface Used for Experiments.**

All other aspects of the eight stories were controlled to the degree possible for comparability. The *sea-level rise* and *presidential campaign donations* conditions (Factor #1) followed Phillip's (2012) cause and effect three-act narrative structure (Table 3.2). Each story was constructed as a set of nine panels (three per act) to repackage linearity in the *longform infographics* and *dynamic slideshows* conditions (Factor #2) in an informationally equivalent manner. Finally, the focus attention solutions (Factor #3) were applied to the protagonist and antagonist in each design, leading to the introduction of two, complementary place-based characters for each story. The overall aesthetic style and layout, the amount and complexity of story content, and the visualization design remained consistent across the eight designs for comparability (Figure 3.3).



**Figure 3.3: Design Consistency across Panels.**

Storytelling Element	Description	Story #1	Story #2	Training Block
Theme	The general thematic category of the visual story, based on Vujaković's (2014) survey of map-based visual stories themes. Note: The full list of themes are provided in Table 1.	A. Politics: internal; 1. Government	D. Environment and Science; 8. Environmental problems/ impacts	G. Economics; 17 Business & finance, industry
Topic	The specific geographic phenomenon or process covered in the visual story.	Presidential campaign donations	Sea-level rise	Online book sales
Title (panel 1)	A condensed, engaging headline for the visual story.	The Presidency's Price Tag: Campaign Donations and the 2012 Presidential Election	Soaking in Water: Sea-Level Rise and Vulnerable Coastal Properties Since 2012	Vanishing Treasures: Online Book Sales and the Decline of Bookstores Since 2012
Summary	A brief introduction to the visual story following a three-act narrative structure.	<b>Purpose:</b> This story follows two swing states--Colorado and Ohio--to explain the impact of campaign donations on the U.S. presidential election results. <b>Problem:</b> Differences in party campaign donations influenced voting results in many swing states during the 2012 Presidential Election. <b>Resolution:</b> Colorado and Ohio represent different alternatives for addressing campaign donations.	<b>Purpose:</b> This story follows two coastal states--New York and North Carolina--to explain the impact of sea-level rise on the vulnerability of coastal properties in U.S. <b>Problem:</b> Rising sea-levels have increased the vulnerability of properties on the East Coast of U.S. since 2012. <b>Resolution:</b> New York and North Carolina represent different alternatives for addressing sea-level rise	<b>Purpose:</b> This story follows two states--Washington and Louisiana--to explain the impact of online book sales on physical bookstores in the U.S. <b>Problem:</b> Booming online book retailers have caused the decline of physical bookstores in many states since 2012. <b>Resolution:</b> Washington and Louisiana represent different alternatives for addressing the boom of online book sales.
Act1: Set-up				
Setting				
*Space	Where the story takes place.	U.S. Swing States	U.S. Eastern Coastal States	U.S. Book Stores
*Time	When the story occurred.	The 2012 U.S. Presidential Election	The 2012 Hurricane Season	2012
Characters				
*Protagonist (accented)	The main character in the story.	Colorado: A swing state whose voting support increased for the Democratic candidate as Democrats gained an advantage in campaign donations	New York: A coastal state whose vulnerability increased as sea-level rose.	Washington: A state whose physical bookstores declined as online book sales increased.
*Antagonist (accented)	The character in opposition to the protagonist	Ohio: A swing state whose voting support was not largely influenced by an advantage in campaign donations by either party.	North Carolina: A coastal state whose vulnerability was not largely influenced by rising sea-levels.	Louisiana: A state whose physical bookstores were not largely influenced by increasing online book sales.
The hook (panel 1)				
*The hook	An exciting scene early in the script that captures the audience's interest and encourages them to continue reading.	Private donations, not public discourse, shape the outcome of the presidential election.	Even small rises in sea-level dramatically increase coastal vulnerability to storms.	Booming online book sales are causing physical bookstores to disappear.
Context				

Fact 1 (Panel 2)	Contextual information readers need to know before introducing the problem.	<p><b>Title:</b> What Is Happening with Our Elections? It Starts with Rising Campaign Costs. <b>Fact:</b> U.S. presidential campaign costs have increased nearly 800% in the past 40 years. <b>Accent:</b> Campaign costs peaked at \$1.74 billion in the 2008 presidential election. <b>Graph:</b> <b>Y value:</b> Presidential Election Costs (\$ Billion); <b>X value:</b> Year.</p>	<p><b>Title:</b> What is Happening with Our Coasts? It Starts with Rising Temperatures. <b>Fact:</b> U.S. average temperatures have increased almost 3 degree F in the past 40 years. <b>Accent:</b> U.S. average temperatures peaked at 54.3 F in 2015. <b>Graph:</b> <b>Y value:</b> Average Temperature (degree F); <b>X value:</b> Year.</p>	<p><b>Title:</b> What is Happening with Our Bookstores? It Starts with Rising Online Retailer Sales. <b>Fact:</b> U.S. average online sales have increased almost 230% in the past 10 years. <b>Accent:</b> U.S. total online sales peaked at \$380 billion in 2016. <b>Graph:</b> <b>Y value:</b> Online Retailer Sales (\$ Billion); <b>X value:</b> Year.</p>
Fact 2 (Panel 3)	Contextual information readers need to know before introducing the problem	<p><b>Title:</b> Why Do Costs Matter? More than 50% of Campaign Funds were from Donations in 2012. <b>Colorado:</b> The average person in Colorado donated \$3.3 during the 2012 presidential election. <b>Ohio:</b> The average person in Ohio donated only \$1.5 during the 2012 presidential election. <b>Legend:</b> <b>legend title:</b> Presidential Campaign Donations; <b>legend description:</b> Average donations per person (\$), 2012 presidential election</p>	<p><b>Title:</b> Why Do Coasts Matter? More than 50% of U.S. Citizens Lived in Coastal Areas by 2012. <b>New York:</b> 3,081 people live in an average square mile of New York coasts. <b>North Carolina:</b> Only 73 people live in an average square mile of North Carolina coasts. <b>Legend:</b> <b>legend title:</b> Coastal Population Density ; <b>legend description:</b> Average people per square mile of coastal area, 2012</p>	<p><b>Title:</b> Why Do Online Sales Matter? More than 30% of U.S. e-Commerce was from Book Sales in 2012. <b>Washington:</b> 51% of Washington e-commerce was from book sales in 2012. <b>Louisiana:</b> Only 8% of Louisiana e-commerce sales was from book sales in 2012. <b>Legend:</b> <b>legend title:</b> Online Book Sales ; <b>legend description:</b> Online book sales as percent of total e-commerce, 2012.</p>
Act 2: Conflict Catalyst (Panel 4)				
Problem	The key issue driving the story, resolved in Act 3.	<p><b>Title:</b> So What? Increasing Donations Pose A Problem... <b>Fact:</b> The Democrat advantage in campaign donations reached \$253 million for the 2012 presidential election. <b>Accent:</b> Democrats received \$51 million more donations than Republicans in September; the largest donations advantage during the 2012 presidential election. <b>Graph:</b> <b>Y value:</b> Cumulative Donation Gap (\$ Million); <b>X value:</b> Month</p>	<p><b>Title:</b> So What? Rising Sea Levels Pose a Problem... <b>Fact:</b> The U.S. average sea levels in 2012 reached 47.8 millimeters above the 2002 average. <b>Accent:</b> Global sea levels rose 8.4 millimeters in 2012, the largest sea-level rise from 2002-2012. <b>Graph:</b> <b>Y value:</b> Cumulative Sea Level Change (Millimeters); <b>X value:</b> Year.</p>	
Tension (Panel 5)				
Tension	The impact of the problem on the protagonist versus the antagonist.	<p><b>Title:</b> ...Particularly for Swing States. <b>Colorado:</b> Democrats increased their support by 6.5% in the swing state of Colorado. <b>Ohio:</b> Democrats only increased their support by 0.7% in the swing state of Ohio. <b>Legend:</b> <b>legend title:</b> Increase in Voting Lead; <b>legend description:</b> Change in Democratic lead (% total), July 2012 poll to Nov 2012 election.</p>	<p><b>Title:</b> ...Particularly for States on the East Coast. <b>New York:</b> The average value of vulnerable properties in coastal areas is \$24,800 in New York. <b>North Carolina:</b> The average value of vulnerable properties in coastal areas is only \$7,730 in North Carolina. <b>Legend:</b> <b>legend title:</b> Property Vulnerability; <b>legend description:</b> Average value of vulnerable coastal properties (\$), 2012</p>	
Plot Points 1 (Panel 6)				

Plot Point 1 (Cause)	One in a sequence of events motivated by the problem that impacts the characters.	<b>Title:</b> A Deeper Look: Democrats Gained their Largest Donation Advantage in Major Cities. <b>Fact:</b> Democrats drew 140% more urban-based donations per person in Colorado than Ohio, largely attributed to the progressive Denver metro area. <b>Accent:</b> The Democrat's gained an advantage of \$4,400,000 in Denver, the highest urban lead in swing states; <b>Legend:</b> <b>legend title:</b> Donation Gap <b>legend description:</b> Democrat advantage in campaign donations (\$), 2012	<b>Title:</b> A Deeper Look: Sea-Levels Rose the Most in Major Stations. <b>Fact:</b> Sea-level rose 50% more in urban-centers in New York compared to North Carolina, particularly due to the dense infrastructure in New York City and Long Island. <b>Accent:</b> Sea-level annual rate in Bergen Point is 4.4 millimeters, the highest rate among stations in coastal states. <b>Legend:</b> <b>legend title:</b> Average Sea-Level Rise <b>legend description:</b> Average annual sea-level rise (millimeters/year), 1992-2012.	
<b>Act 3: Resolution</b>				
<b>Climax (Panel 7)</b>				
Plot Point 2 (effect)	One in a sequence of events motivated by the problem that impacts the characters.	<b>Title:</b> As a Result, Campaign Donations Have a Different Influence on Election Results in Swing States like Colorado versus Ohio. <b>Colorado:</b> Every \$100 advantage for the Democrats bought 7.5 votes in Colorado. <b>Ohio:</b> Every \$100 advantage for the Democrats bought only 2.8 votes in Ohio.	<b>Title:</b> As a Result, Sea-level Rise Has a Different Impact on Vulnerability in Coastal States like New York versus North Carolina. <b>New York:</b> Every inch in sea-level rise exposes \$ 3,900 of property in New York. <b>North Carolina:</b> Every inch in sea level rise only exposes \$ 1,400 of property in North Carolina.	
<b>Resolution (Panel 8)</b>				
Resolution (Panel 8)	The solution (or solutions) to the key problem and tension.	<b>Title:</b> What's Next? Colorado and Ohio Represent Different Alternatives for Addressing Campaign Donations. <b>Colorado:</b> Colorado has imposed new regulations to limit campaign funding since the 2012 presidential election. <b>Ohio:</b> At the same time, Ohio has failed to act on campaign funding.	<b>Title:</b> What's Next? New York and North Carolina Represent Different Alternatives for Addressing Sea-level Rise. <b>New York:</b> New York has invested considerable public funds to prevent sea-level rise related crises. <b>North Carolina:</b> At the same time, North Carolina has failed to act on sea-level rise.	
<b>Denouement (Panel 9)</b>				
Cliffhanger	The dramatic ending, leaving open strands for audience to ponder.	<b>Title:</b> What Do You Think We Should Do As a Nation? <b>Colorado:</b> The Democrats are predicted to make only a 2.3% gain in Colorado in the 2020 presidential election if campaign funding remains consistent from 2016. <b>Ohio:</b> The Republicans are predicted to make a whopping 12.5% gain in Ohio in the 2020 presidential election if campaign funding remains consistent from the 2016. <b>Legend:</b> <b>legend title:</b> Voting Results Predictions, 2020 Presidential Election; <b>legend description:</b> Predicted Republican voting lead; Predicted Democratic voting lead	<b>Title:</b> What Do You Think We Should Do as a Nation? <b>New York:</b> The value of vulnerable properties per person in New York only is predicted to increase to \$290 by 2020 if sea-levels continue to increase at a consistent rate. <b>North Carolina:</b> The value of vulnerable properties per person in North Carolina is predicted to increase a surprising \$325 by 2020 if sea-level continue to increase at a consistent rate. <b>Legend:</b> <b>legend title:</b> Predicted Property Vulnerability; <b>legend description:</b> Increased value of vulnerable coastal properties per person (\$), 2020 Prediction	

Table 3.2: Story Content Table.

### 3.3 Procedure

#### 3.3.1 Training Block

After receiving information about the survey purpose and providing consent, participants completed a training block to combat learning effects between the two stories. The training block included the opening three panels of a third visual story on U.S. book sales that followed the same design rules as the other visual stories (Table 3.2). Participants then answered example questions to get a feel for the Qualtrics survey instrument. Responses to the training block were not recorded and participants were allowed to review the training block until they felt comfortable with the visual story.

#### 3.3.2 Assignment

Participants were randomly assigned into one of four testing groups. Factors #1 (*Theme*) and #3 (*Tropes*) were assigned within subjects, resulting in each participant completing two survey blocks with each block comprising a unique story and set of follow-up questions. Assignment within Factors #1 and #3 conditions was balanced so that each possible combination was viewed by approximately one quarter of the study participants (Table 3.3). Factor #2 (*Genre*) was assigned between groups so that participants viewed just one linear structure during the survey, limiting confusion over layout and interface changes to the survey instrument between blocks one and two.

Participant group	Sample Size (n=125 total)	First viewing story	Second viewing story
Group I	33	Story 1	Story 2
Group II	30	Story 3	Story 4
Group III	31	Story 5	Story 6
Group IV	31	Story 7	Story 8

**Table 3.3: Experiment Group Assignment.**

### 3.3.3 Questions

Common measures of effectiveness include speed, completeness, and correctness (Sweeney, Maguire, & Shackel, 1993). However, Kosara and Mackinlay (2013) and Figueiras (2014) argue that the effectiveness of visual stories should instead be based on engagement and interest when reading the story, the ability to remember key points in the story, and the ability to make better informed decisions after reading the story.

Accordingly, participants responded to three kinds of questions about the story within each block, with each set of questions separated into three different survey pages: retention, comprehension, and preference. Participants were not allowed to return to the story when answering these questions. After reviewing the story, participants first were presented with the *comprehension* page, which included a single open-ended question requiring participants to use their own words to summarize the content of the story. Participants then navigated to the *preference* page, which included a set of seven-point Likert scales to capture participant reactions to and feelings about the story. Preference responses also included measures of core affect, including arousal and valence (Griffin & McQuoid, 2012). Finally, the *retention* page included 12 multiple choice questions built from benchmark mapping tasks (Roth, 2013). The questions varied on the level of predicted difficulty: three ordinal comparison tasks (easiest), three ordinal ranking tasks, and six numerical identification tasks (hardest). The retention questions were placed at the end of the block to reduce short-term recall and the twelve questions were randomized to avoid learning effects between stories; retention responses are presented first in Chapter 4, as the qualitative comprehension responses enrich the quantitative retention analysis. Participants completed this set of questions for both story blocks, resulting in responses to 250 unique blocks through the sample of 125 participants. The specific set of questions



included in the survey was narrowed from a larger candidate set through feedback during the pilot study.

#### *3.3.4 Exit Survey*

After responding to questions about both stories, participants completed an exit survey to determine their level of knowledge and interest in the story topic and to characterize individual differences that might influence retention, comprehension, and preference. The exit survey included questions on demographics (age, gender, living region and race/ethnicity), education, motivation, ability, and beliefs/bias. The complete protocol is available in Appendix E.

### *3.4 Analysis*

Each factor in the study design served as an independent variable for quantitative analysis, with a null hypothesis of no difference between conditions. I used t-tests assuming equal variances to assess the influence of the factors on collected preference and retention dependent variables (see below for treatment of the comprehension response). I did not expect to obtain significance between themes given the control in the story designs. Background measures on ability, expertise, motivation, and beliefs/bias were treated as potential interaction effects. The background measures used ordinal Likert scales from 1 (strongly disagree) to 7 (strongly agree), hence Spearman's rank correlation coefficient was applied for analyzing the influences of these background measures on retention, comprehension, and preferences (Norman, 2010). Two-sample t-tests were applied to compare the influences of different theme, genres, and tropes conditions on retention and comprehension. Nonparametric testing was required for statistical analysis of Likert responses because the random variable recorded by a Likert is not continuous (i.e., measurement of the variable is on the ordinal level of measurement rather than interval/ratio) and Likert responses typically are not normally distributed (Roth 2009). Hence,

Mann-Whitney U tests (Wilcoxon–Mann–Whitney test) were applied to analyze influences by themes, genres, and tropes on preferences.

Open-ended questions were used to capture participants’ comprehension of the stories contents. I applied tenets of qualitative data analysis (QDA) methods to analyze open-ended responses to the comprehension questions in the survey (Caudle, 2004). Code schemes were developed based on the narrative structure introduced in Chapter 2, and included: space, time, protagonist, antagonist, problem, cause, effect/ resolution, and the cliffhanger, as well as a separate code to capture any mistakes in comprehension. Thus, the coding scheme measured if purposeful treatment of these narrative elements in the visual story design resonated in reader comprehension. Table 3.4 includes specific codes for two story themes. The codes were binary based on presence or absence: a “1” was recorded if a code was mentioned. Multiple mentions were not redundantly coded for frequency, as most responses were only 4-5 sentences in length. The first 10% of the comprehension responses were coded by two, independent coders to hone code definitions and clarify ambiguity in the coding scheme. Table 3.5 summarizes the quantitative and qualitative methods I used during analysis.

<i>Theme</i>	<i>Space</i>	<i>Time</i>	<i>Protagonist</i>	<i>Antagonist</i>	<i>Problem</i>	<i>Tension</i>	<i>Cause</i>	<i>Effect/Resolution</i>	<i>Cliffhanger</i>	<i>Mistake/confusion</i>
Sea-level rise	U.S. Eastern Coastal States	The 2012 Hurricane Season	New York	North Carolina	Increasing sea level/ sea-level rise	Property values/ vulnerable properties	urban centers/ density of property/ population	Different action/policies between New York & North Carolina	2020 prediction/ future	Mistake or confusion in participant s’ answers
Presidential campaign donations	U.S. swing states	The 2012 U.S. Presidential Election	Colorado	Ohio	Increasing campaign donations/ increased Democrat donations advantages	impact on election votes/ election result/ winning	Urban based/ density of population	Different actions or policies between Colorado and Ohio	2020 election prediction	Mistake or confusion in participant s’ answers

**Table 3.4: Code schemes.**

<i>Independent Variables (IV)</i>	<i>Dependent Variables (DV)</i>	<i>Analysis methods</i>
Theme (sea-level rise, presidential campaign donation)	Retention	Two-sample t-test
	Comprehension	Qualitative data analysis, two-sample t-test
	Preferences	Mann-Whitney U test
Genre (Longform infographics, dynamic slideshows) (Research question #1)	Retention	Two-sample t-test
	Comprehension	Qualitative data analysis, two-sample t-test
	Preferences	Mann-Whitney U test
Tropes (color highlighting and leader lines) (Research question #2)	Retention	Two-sample t-test
	Comprehension	Qualitative data analysis, two-sample t-test
	Preferences	Mann-Whitney U test
Individual differences (Research question #3)	Retention	Spearman's rank correlation coefficient
	Comprehension	Qualitative data analysis, Spearman's rank correlation coefficient
	Preferences	Spearman's rank correlation coefficient

**Table 3.5: Analysis Methods for Independent Variables and Dependent Variables.**

## CHAPTER 4: RESULTS

### 4.1 Overall Results

A total of 125 ( $n = 125$ ) participants completed the visual storytelling study. As described in Chapter 3, participant survey responses about the story designs were organized by retention, comprehension, and preference.

Participants were required to answer twelve retention tasks for each story, resulting in 24 retention tasks per participant and 3,000 collected retention responses in total. Overall, participants responded with an average accuracy of 72.08% (SD: 16.03%) across all retention tasks, suggesting that the retention tasks were neither obvious nor impossible (Table 4.1). As described in Chapter 3, the retention tasks varied by their level of cognitive sophistication and associated expected difficulty. Participants responded to three kinds of retention tasks: compare (ordinal), rank (ordinal), and identify (numerical). As expected, participants performed the best on the simpler compare (ordinal) tasks and worst on the more difficult to remember identify (numerical), with the accuracy for rank (ordinal) in the middle. Across all visual stories, participants answered 82.14% (SD: 15.48%) of compare (ordinal) tasks correctly, 73.72% (SD: 14.53%) of rank (ordinal) tasks correctly, and 66.22% (SD: 14.52%) of identify (numerical) tasks correctly.

	Sample size	Compare (Ordinal)		Rank (Ordinal)		Identify (Numerical)		Total	
		mean	SD	mean	SD	mean	SD	Mean	SD
Group I	792	83.84%	14.04%	74.75%	18.74%	68.69%	14.52%	73.99%	15.78%
Group II	720	86.11%	20.70%	75.00%	14.41%	73.61%	13.81%	77.08%	15.95%
Group III	744	79.03%	14.39%	69.89%	13.32%	59.68%	14.71%	67.07%	15.97%
Group IV	744	79.57%	15.08%	75.27%	14.52%	62.90%	12.87%	70.16%	15.22%
Total	3,000	82.14%	15.48%	73.72%	14.53%	66.22%	14.52%	72.08%	16.03%

**Table 4.1: Participant Performance by Retention Tasks.** Diverging color scheme: the darker the red indicates higher value; the darker the blue indicates a lower value, with white centered on 50%.

To describe participant comprehension of the stories, I applied content analysis to open-ended summaries drafted after reviewing the stories in the participants' own words. As introduced in Chapter 3, the coding scheme was developed based on the narrative structure used for the visual stories, and included codes for the setting (separate codes for space and time), protagonist, antagonist, problem, cause, effect/resolution, and the cliffhanger, as well as a code to capture any errors. Table 4.2 provides the extensiveness that each code was mentioned across participants (out of 250 maximum).

Overall, participants described 47.99% of the total topics included in the comprehension coding scheme, a relatively rich discussion about the tested stories given the general audience and open-ended format of the comprehension question. There were several notable patterns in the comprehension coding worth discussing in the aggregate. Nearly all participants (96.00%) clearly stated the problem of the story in their comprehension response, suggesting that the problem was the most salient narrative element in both visual stories. While perhaps an expected finding, confirming that readers focus on the problem is useful for cartographers and data journalists, as this element should be emphasized in the story title and redundantly accented as a central motif throughout the story. The next three most commonly mentioned codes related to the characters in the story: 69.20% of participants described the tension—or the how the problem impacts the key characters—59.60% described the protagonist, and 52.40% described the antagonist. This suggests that the focus attention strategies applied to the characters were relatively successful (although differentially so, as described in Section 4.3). This description also provides evidence that readers can conceptualize places or regions as characters in an explicitly geographic story, presenting an opportunity to add dramatic narrative structuring to our map designs. While both stories used Phillip's (2012) cause and effect structure, the cause

(32.40%) was discussed much less frequently than the effect (50.80%), showing a bias towards outcomes compared to drivers during story comprehension. When discussed, the specific cause often was collapsed with the overarching problem, suggesting greater clarification and differentiation may have been needed in the story designs. Finally, space (26.78%), the cliffhanger (26.75%), and time (18.00%) were described infrequently. Given that the story was map-based, it was surprising that the geographic location and, to a lesser degree, the timeframe were not discussed more in the comprehension responses, although arguably the visual accenting of place-based characters should divert attention away from the overall spatiotemporal context. The limited description of the cliffhanger on the final story panel also was surprising; suggesting more thought was needed in the story design to stimulate readers to “fill the gaps” at the end of the story with their own experiences and predictions, following Gershon and Page (2001: 35).

In contrast, only 12.39% of the responses included a mistake in comprehension. While not frequent, mistakes in the comprehension responses generally fell into one of three common issues. First, participants at times stated unrelated information to the story. There was an interesting difference in unrelated information by the story theme: 10 responses about the *presidential campaign donations* (8%) contained unrelated information, while only 4 responses to the *sea-level rise* story included unrelated information. Because the experiment was conducted four months after 2016 presidential election, participants may have drawn more from personal experience and opinion when responding to the *presidential campaign donations* story. The second common issue was an explicit error in understanding where a participant incorrectly interpreted a component of the three-act narrative. 10 answers included errors in comprehension, split evenly by theme. The third mistake was participant commentary on the story designs themselves, a misinterpretation of the comprehension questions, not necessarily the stories. Five

responses included commentary on the *presidential campaign donations* story but only 2 on the *sea-level rise* story, again perhaps an indicator of the timeliness of the *presidential campaign donations* topic. Because the number of mistakes was small, discussion below focuses on differential patterns of other comprehension codes covering the narrative elements of the stories. Overall, comprehension results show that three-act narrative structure was effectiveness in visual storytelling.

	Sample size	Problem	Tension	Protagonist	Antagonist	Effect/ resolution	Cause	Space	Cliffhanger	Time	Total	Mistake/ confusion
Group I	66	98.48%	68.18%	63.64%	51.52%	57.58%	27.27%	31.82%	28.79%	18.18%	49.49%	12.12%
Group II	60	100%	71.67%	56.67%	50.00%	43.33%	45.00%	33.33%	25.00%	18.33%	49.26%	10.00%
Group III	62	93.55%	66.13%	58.06%	53.23%	53.23%	30.65%	19.35%	29.03%	11.29%	46.06%	16.13%
Group IV	62	91.94%	70.97%	59.68%	54.84%	48.39%	27.42%	22.58%	24.19%	24.19%	47.13%	11.29%
Total	250	96.00%	69.20%	59.60%	52.40%	50.80%	32.40%	26.78%	26.75%	17.99%	47.99%	12.39%

**Table 4.2: Overall Comprehension.** Diverging color scheme: the darker the red indicates higher value; the darker the blue indicates a lower value, with white centered on 50%.

The final collected measure about the stories was personal preference. Participants responded to seven Likert scale questions after viewing each story, resulting in 2,000 responses about story preferences in total (Table 4.3). The two strongest preference registers were on interest and agreement, receiving an average response of 5.0/7 for both measures. Thus, the stories overall captured participant interest—demonstrating the value of visual communication using storytelling—and participants generally agreed with the cause/effect narrative used to structure the story. Interestingly, there was marginal overall affective impact by arousal, with positive arousal (excitement; 3.5/7) and negative arousal (boredom; 3.1/7) both receiving less than the “neither agree nor disagree” midpoint 4.0 out of 7. There was a slight positive affective response on the hedonic scale, with participants finding the experience more pleasant

(enjoyment; 4.4/7) than unpleasant (upsetting; 3.2/7). Methodologically, it would have been interesting to capture a measure of core affect at the start of the survey to see if a shift occurred from the baseline after reviewing each story.

	Sample size	Interest: The visual story interested me		Agreement: I agree with the visual story		Concern: The visual story concerned me		Enjoyment: I enjoyed the visual story		Influence: The visual story did not influence my beliefs about topic		Excitement: The visual story excited me.		Upsetting: I was upset by visual story		Boredom: The visual story bored me.	
		mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
Group I	528	5.1	1.6	5.5	1.4	4.7	1.9	4.5	1.6	3.3	1.7	3.4	1.7	3.1	1.8	2.9	1.8
Group II	480	5.1	1.8	5	1.5	4.1	1.5	4.4	1.8	3.9	1.8	3.3	1.6	2.7	1.6	2.9	1.8
Group III	496	5.1	1.7	4.9	1.5	4.6	1.9	4.5	1.9	4.2	2	3.7	1.8	3.4	2	3.1	2
Group IV	496	4.8	1.9	4.8	1.8	4.5	1.9	4.3	1.8	3.8	1.9	3.6	1.7	3.5	1.7	3.6	1.9
Total	2,000	5.0	1.7	5.0	1.6	4.5	1.9	4.4	1.8	3.8	1.9	3.5	1.7	3.2	1.8	3.1	1.9

**Table 4.3: Participant Preference by Groups. Diverging color scheme centered on 4.0: the darker the red indicates higher value; the darker the blue indicates a lower value.**

## 4.2 The Three-Act Narrative (RQ #1)

As described in Chapter 3, the study made use of two different story themes from Vujaković's (2014) taxonomy (Factor #1): *U.S. sea-level rise* (Politics, Internal) and *U.S. presidential campaign donations* (Environment and Science). All participants viewed both story themes, with the order balanced to combat learning effects. Despite the difference in theme, the stories were designed following a consistent visual and three-act narrative structure. Therefore, I did not expect to find significant differences in retention, comprehension, or preference for Factor #1.

Starting with retention (Table 4.4), the average accuracy on retention tasks about *sea-level rise* was 73.57% (SD: 16.11%), while the average accuracy on retention tasks about the *presidential campaign donations* was slightly lower at 70.59% (SD: 15.98%). A set of two-sample t-tests were conducted to compare the retention accuracy between themes. There was no



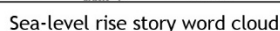
statistical difference at  $\alpha=0.05$  regarding overall accuracy ( $t = 1.511$ ,  $p = 0.228$ ), and thus in aggregate the story theme did not impact retention. This is a potentially exciting finding for cartographers and data journalists, as the specific theme may not influence retention for a general audience as long as the graphic is constructed following tenets of visual storytelling. Visual stories, therefore, do not need to cover tragic topics like violence, suffering, and death, nor include sensationalized text, imagery, and graphics, to be effective. Looking at specific retention tasks, there also was no significant difference between themes on the easy compare (ordinal) tasks ( $t = -0.742$ ,  $p = 0.469$ ) and the difficult identify (numerical) tasks ( $t = 0.458$ ,  $p = 0.649$ ). However, there was a significance difference between themes in retention for the rank (ordinal) tasks ( $t = 2.361$ ,  $p = 0.028$ ). The simplest explanation for this significant difference is the wording for one of the tasks for the *sea-level rise* condition: “Which year from 2002 to 2012 exhibited the highest annual rise in sea levels?” Because the highest annual rise was in 2012, the most recent year listed in the options, participants were likely more easily able to correctly guess based on knowledge of an overall increasing trend, even though the question asked about year-to-year change and not the overall trend.

	Sample size	Compare (Ordinal)		Rank (Ordinal)		Identify (Numerical)		Total	
		Mean	SD	mean	SD	mean	SD	mean	SD
<i>Sea-level rise</i>	1,500	79.78%	19.68%	80.12%	13.19%	67.19%	13.31%	73.57%	16.11%
<i>Presidential campaign donations</i>	1,500	84.50%	10.08%	67.33%	13.35%	65.25%	15.86%	70.59%	15.98%
<b>Total</b>	<b>3,000</b>	<b>82.14%</b>	<b>15.48%</b>	<b>73.72%</b>	<b>14.53%</b>	<b>66.22%</b>	<b>14.52%</b>	<b>72.08%</b>	<b>16.03%</b>
Differences		t-test	p-value	t-test	p-value	t-test	p-value	t-test	p-value
T-test results		-0.742	0.469	2.361**	0.028	0.458	0.649	1.511	0.228

**Table 4.4: Participant Performance by Themes.** Note: \*\* Two measures are significantly correlated at a two-tailed significance level of 0.05. Diverging color scheme: the darker the red indicates higher value; the darker the blue indicates a lower value, with white centered on 50%.

The comprehension coding for both themes generally followed the pattern observed in the aggregate (Table 4.5). Overall, participants described 49.60% of the total topics included in the comprehension coding scheme for the *sea-level rise* theme, and 46.40% for the *presidential campaign donations* theme. A two-sample t-test returned no statistical difference at  $\alpha=0.05$  in overall comprehension between themes ( $t = 0.582$ ,  $p = 0.575$ ). As reported in Section 4.1, participants made fewer mistakes in the *sea-level rise* condition (8.80%) than the *presidential campaign donations* condition (16.00%), although a two-sample t-test again returned no statistical difference ( $t = -2.634$ ,  $p = 0.078$ ).

Figure 4.1 provides a pair of word clouds from the participants' responses to the open-ended comprehension question. Looking at specific comprehension codes, the problem was discussed equally for both themes: 96.00% of the participants described the problem in the *sea-level rise* condition and the *presidential campaign donations* conditions. There was similarly minimal discrepancy in comprehension between conditions in the tension (67.20% for *sea-level rise*; 71.20% for *presidential campaign donations*) and the protagonist (67.20% and 65.00%, respectively), although the antagonist showed slightly more separation between themes (56.00% and 48.80%, respectively). None of these differences were significant. There are several notable differences between the themes in the less frequently described comprehension topics, such as an increased emphasis on the cause and effect in the *sea-level rise* story, and an increased emphasis on the setting in the *presidential campaign donation* story. However, two-sample t-tests only returned significance for the difference in the space code between two story themes ( $t = -3.178$ ,  $p = 0.050$ ). This perhaps suggests that participants were more familiar with swing states (space of *presidential campaign donations* theme) than low-lying east coastal states (space of *sea-level rise* theme), given that the experiment was just four months after the 2016 presidential election.



**Figure 4.1: Words Clouds Generated from Comprehension.**

	Sample size	Problem	Tension	Protagonist	Antagonist	Effect/resolution	Cause	Space	Challenger	Time	Total	Misdeed/corruption											
Sex-level rise	125	96.00%	67.20%	67.20%	56.00%	57.60%	44.00%	18.40%	28.00%	12.00%	49.60%	8.80%											
Presidential campaign donations	125	96.00%	71.20%	65.00%	48.80%	44.00%	20.80%	35.20%	25.60%	24.00%	46.40%	16.00%											
Total	250	96.00%	69.20%	59.60%	52.40%	50.80%	32.40%	26.80%	26.80%	18.00%	47.99%	12.39%											
Difference		t	p	t	p	t	p	t	p	t	p	t	p										
T-test		0	1	1212	0312	2460	0091	2635	0078	1618	0204	3.170	0051	3.178**	0080	0600	0591	1640	0200	0582	0575	12635	0078

**Table 4.5: Comprehension by Story Themes. Note: \*\* Two measures are significantly correlated at a two-tailed significance level of 0.05. Diverging color scheme: the darker the red indicates higher value; the darker the blue indicates a lower value, with white centered on 50%.**

As with story comprehension, preference for individual story themes largely followed patterns observed in the aggregate. The largest difference in preference between themes regarded participant concern: participants overall were concerned by the *sea-level rise* story (4.9/7.0), but were neither concerned nor unconcerned with the presidential campaign donation story (4.0/7.0). A Mann-Whitney U test (non-parametric t-test) found a statistical difference in concern ( $w = 16$ ,

$p = 0.029$ ). Again, this is perhaps explained by the timing of the study, which was conducted four months after the polarizing presidential election of 2016. Further, this finding also marks a potentially promising trend in the U.S. towards public awareness of and concern for climate change and its consequences. There is no statistical difference in other measures of preference between the two themes. Hence, on most registers, the story theme did not influence retention, comprehension, or preference, following expectations.

	Sample size	Interest: The visual story interested me		Agreement: I agree with the visual story		Concern: The visual story concerned me		Enjoyment: I enjoyed the visual story		Influence: The visual story did not influence my beliefs about topic		Excitement: The visual story excited me.		Upsetting: I was upset by visual story		Boredom: The visual story bored me.	
		mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
Sea-level rise	1,000	5.1	1.6	5.2	1.5	4.9	1.8	4.4	1.7	3.6	1.9	3.5	1.7	3.5	2	3	1.9
Presidential campaign donations	1,000	4.8	1.8	4.8	1.6	4.0	1.9	4.3	1.8	4.0	1.8	3.5	1.7	2.9	1.7	3.1	1.9
Total	2,000	5.0	1.7	5.0	1.6	4.5	1.9	4.4	1.8	3.8	1.9	3.5	1.7	3.2	1.8	3.1	1.9
Mann-Whitney U test		W		P		W		P		W		P		W		P	
Statistic results		11	0.486	14.5	0.081	16**	0.029	8	1	5.5	0.561	8.5	1	14.5	0.083	8	1

**Table 4.6: Participant Preference by Story Themes.** Note: \*\* Two measures are significantly correlated at a two-tailed significance level of 0.05. Diverging color scheme centered on 4.0: the darker the red indicates higher value; the darker the blue indicates a lower value.

### 4.3 Story Genre (RQ #2)

The visual story designs also varied by genre, with two of Roth's (2016) six map-based visual storytelling genres included in the study (Factor #2): *longform infographics* and *dynamic slideshows*. Participants in Groups I and II viewed their stories as *longform infographics* and participants in Groups III and IV viewed their stories as *dynamic slideshows*.

Unlike story theme, story genre did prove to impact retention (Table 4.7). Participants responded to retention tasks with an average accuracy of 75.93% (SD: 15.90%) for stories

presented as *longform infographics*, but only 70.82% (SD: 15.53%) to tasks covering the exact same theme, but presented as *dynamic slideshows*. A two-sample t-test found the difference in retention between the *longform infographics* and *dynamic slideshows* conditions statistically significant ( $t = 6.381$ ,  $p = 0.008$ ). Thus, participants had a more difficult time remembering facts when the visual story was fragmented as a dynamic slideshow. This is an important finding for cartography and visual storytelling, as well as science communication and pedagogy generally, as material more commonly is presented in a slide deck (e.g., Apple Keynote or Microsoft PowerPoint) instead of a continuous list. Further, this suggests potentially preferred interactive navigation of visual stories using new media, as *longform infographics* enabled scrolling at a user-controlled pace, whereas the *dynamic slideshows* dosed information at a designer-controlled pace.

Looking at individual retention tasks, participants expectedly performed best on the easy compare (ordinal) tasks and worst on the difficult identify (numerical) tasks, regardless of genre condition. However, the accuracy was higher with *longform infographics* than *dynamic slideshows* within each kind of retention task. Interestingly, two-sample t-tests found no significant difference in accuracy rate on compare (ordinal) ( $t = 0.893$ ,  $p = 0.382$ ) or rank (ordinal) ( $t = 0.379$ ,  $p = 0.708$ ) retention tasks at  $\alpha=0.05$ , but did find a significant difference in identify (numerical) tasks between genres ( $t = 2.478$ ,  $p = 0.017$ ). Thus, while *longform infographics* outperformed *dynamic slideshows* across tasks, this benefit grew with the difficulty of the tasks and only resulted in significant differences when participants needed to recall numerical information. Thus, *longform infographics* helped participants consider and retain quantitative details that are potentially important when weighing new evidence about the story theme in the future.

	Sample size	Compare (Ordinal)		Rank (Ordinal)		Identify (Numerical)		Total	
		mean	SD	mean	SD	mean	SD	mean	SD
<i>Longform infographics</i>	1,512	84.97%	16.91%	74.87%	15.94%	70.95%	14.23%	75.93%	15.90%
<i>Dynamic slideshows</i>	1,488	79.30%	14.06%	72.58%	13.58%	60.59%	13.48%	70.82%	15.53%
<b>Total</b>	<b>3,000</b>	<b>82.14%</b>	<b>15.48%</b>	<b>73.72%</b>	<b>14.53%</b>	<b>66.22%</b>	<b>14.52%</b>	<b>72.08%</b>	<b>16.03%</b>
Differences		<b>t-test</b>	<b>p-value</b>	<b>t-test</b>	<b>p-value</b>	<b>t-test</b>	<b>p-value</b>	<b>t-test</b>	<b>p-value</b>
T-test results		0.893	0.382	0.379	0.708	<b>2.478**</b>	<b>0.017</b>	<b>6.381**</b>	<b>0.008</b>

**Table 4.7: Participant Performance by Genres.** Note: \*\* Two measures are significantly correlated at a two-tailed significance level of 0.05. Sequential color scheme for mean: the darker the red indicates higher percentage of correct responses.

Story genre also impacted comprehension (Table 4.8). Overall, participants described 49.38% of the total topics when presented as a *longform infographics* and only 46.59% of the total topics when presented as a dynamic slideshow. A two-sample t-test on overall comprehension returned significance at  $\alpha=0.05$  ( $t = 2.347$ ,  $p = 0.047$ ). While overall comprehension was significant, a two-sample t-test resulted in no significant difference in the number of mistakes or confusions between genres ( $t = 0.676$ ,  $p = 0.547$ ).

Interestingly, the difference in overall comprehension between genre conditions was primarily explained by differential discussion of the problem. While nearly all (99.21%) participants discussed the problem when viewing *longform infographics*, only 92.74% of participants discussed the problem when viewing *dynamic slideshows*. A two-sample t-test found this difference significant at  $\alpha=0.05$  ( $t = 3.873$ ,  $p = 0.030$ ). Therefore, the *dynamic slideshows* format and navigation caused a small set of participants to miss the main problem altogether in their discussion, a fatal erasure. Thus, while the retention measures indicate that the *dynamic slideshows* inhibited recall of specific, numerical details for many participants, the comprehension measures indicate that the *dynamic slideshows* inhibited development of a general problem understanding for small set of participants; this is the “worst of both worlds”. Two-sample t-tests did not reveal significance between genres for any other individual

comprehension codes. A likely reason of why *dynamic slideshows* was not as effective as *longform infographics* is the manner by which *dynamic slideshows* enforce linearity. Clicking through the panels in *dynamic slideshows* breaks the flow of the story, requiring reloading of new content that may be delayed due to bandwidth issues.

	Sample size	Problem	Tension	Protagonist	Antagonist	Effect/ resolution	Cause	Space	Cliffhanger	Time	Total	Mistake/ confusion
<i>Longform infographics</i>	126	99.21%	69.84%	60.32%	50.79%	50.79%	35.71%	32.54%	26.98%	18.25%	49.38%	11.10%
<i>Dynamic slideshows</i>	124	92.74%	68.55%	58.87%	54.03%	50.81%	29.03%	20.97%	26.61%	17.74%	46.59%	13.71%
<b>Total</b>	<b>250</b>	<b>96.00%</b>	<b>69.20%</b>	<b>59.60%</b>	<b>52.40%</b>	<b>50.80%</b>	<b>32.40%</b>	<b>26.80%</b>	<b>26.80%</b>	<b>18.00%</b>	<b>47.99%</b>	<b>12.39%</b>
<i>Difference</i>		t p	t p	t p	t p	t p	t p	t p	t p	t p	t p	t p
<i>T-test</i>		3873** 00	0728 0519	0389 0724	0196 0391	0162 0882	0984 0398	2270 0108	0167 0878	0115 0916	2347** 0047	-0676 0547

**Table 4.8: Comprehension by Genres.** Note: \*\* Two measures are significantly correlated at a two-tailed significance level of 0.05. Diverging color scheme: the darker the red indicates higher value; the darker the blue indicates a lower value, with white centered on 50%.

As with story comprehension, preference for individual story genres largely followed patterns observed in the aggregate (Table 4.9). The largest difference in preference between genres was if participants found the stories upsetting, although participants overall were not upset by the *dynamic slideshows* (upsetting; 3.5/7.0) or the *longform infographics* (upsetting; 2.9/7.0). A Mann-Whitney U test (non-parametric t-test) found no statistical difference on the degree to which participants found the genres upsetting ( $w = 2.5$ ,  $p = 0.147$ ). Participants overall largely agreed more with stories presented as *longform infographics* (agreement; 5.2/7.0) than those presented as *dynamic slideshows* (agreement; 4.8/7.0), although a Mann-Whitney U test did not find this difference significant ( $w = 12.5$ ,  $p = 0.245$ ). Thus, overall the different genres

did not significantly impact user preference, an interesting result given the negative influence of the *dynamic slideshows* on retention and comprehension.

	Sample size	Interest: The visual story interested me		Agreement: I agree with the visual story		Concern: The visual story concerned me		Enjoyment: I enjoyed the visual story		Influence: The visual story did not influence my beliefs about topic		Excitement: The visual story excited me.		Upsetting: I was upset by visual story		Boredom: The visual story bored me.	
		mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
<i>Longform infographics</i>	1,008	5.1	1.6	5.2	1.5	4.4	1.9	4.4	1.7	3.6	1.8	3.3	1.6	2.9	1.8	2.9	1.8
<i>Dynamic slideshows</i>	992	4.9	1.8	4.8	1.6	4.5	1.9	4.4	1.8	4.0	2.0	3.7	1.7	3.5	1.9	3.3	2.0
<b>Total</b>	<b>2,000</b>	<b>5.0</b>	<b>1.7</b>	<b>5.0</b>	<b>1.6</b>	<b>4.5</b>	<b>1.9</b>	<b>4.4</b>	<b>1.8</b>	<b>3.8</b>	<b>1.9</b>	<b>3.5</b>	<b>1.7</b>	<b>3.2</b>	<b>1.8</b>	<b>3.1</b>	<b>1.9</b>
Mann-Whitney U test		W	P	W	P	W	P	W	P	W	P	W	P	W	P	W	P
Statistic results		9	0.886	12.5	0.245	6	0.663	9	0.885	4.5	0.38	3.5	0.234	2.5	0.147	3.5	0.245

**Table 4.9: Participant Preference by Genres.** Diverging color scheme centered on 4.0: the darker the red indicates higher value; the darker the blue indicates a lower value.

Table 4.10 displays participants' general feedback on alternative genres in the exit survey. Interestingly, participants viewing the story in *longform infographics* had a low interest in *dynamic slideshows* (3.1/7.0), while participants viewing the *dynamic slideshows* were more receptive to *longform infographics* (3.9/7.0). Further, participants who viewed the *longform infographics* were less interested in a non-visual, text-based write-up (2.7/7.0) compared to those viewing *dynamic slideshows* (3.6/7.0). Both findings indicate a preference for visual methods when viewing *longform infographics*. That said, participants were biased by the genre they viewed when responding to the exit survey, preferring *longform infographics* (4.4/7.0) or *dynamic slideshows* (4.7/7.0) over other listed genres.).



	I liked vertically scrolling through all content	I liked clicking through each panel in the slideshow.	I instead would have preferred clicking through each panel in the slideshow.	I instead would have preferred scrolling through all content	I instead would have preferred a video animation with narration.	I instead would have preferred a single static map poster.	I instead would have preferred a single interactive map.	I instead would have preferred a printed, text-based write-up.	I instead would have preferred a website with a text-based write-up.
<i>Longform infographics</i>	4.4		3.1		4.2	3.5	3.8	2.7	3.1
<i>Dynamic slideshows</i>		4.7		3.9	4.4	3.2	3.7	3.6	3.4

**Table 4.10: Genre Preference.** Diverging color scheme centered on 4.0: the darker the red indicates higher value; the darker the blue indicates a lower value.

#### 4.4 Story Trope (RQ #3)

The visual stories also varied by their tropes, with the study including two solutions for Roth's (2016) focus attention trope (Factor #3): *color highlighting* using high contrasting color in the graphics and *leader lines* connecting text to the graphics. Trope designs were assigned within participants, with each participating viewing a story with *color highlighting* and *leader lines*. The tropes order was balanced to combat learning effects.

Like genres, trope designs also significantly impacted retention (Table 4.11). Participants responded to retention tasks with an average accuracy of 75.02% (SD: 15.98%) for stories presented with *leader lines* as the focus attention strategy, but only 69.13% (SD: 15.70%) to stories presented with *color highlighting*. A two-sample t-test found this difference statistically significant ( $t = -6.060$ ,  $p = 0.0262$ ). This is an important finding for interactive cartography as well as visual storytelling, as the leader lines made it easier to associate text and graphics—and to retain this association—than use of high contrasting colors. This result is consistent with Griffin and Robinson (2015) discovery in the context of coordinated interaction for exploratory geovisualization, suggesting that leader lines are more visually salient and thus improve map reading and interpretation.

Looking at individual retention tasks, participants expectedly performed best on the easy compare (ordinal) tasks and worst on the more difficult identify (numerical) tasks, regardless of trope condition. However, the accuracy was higher with *leader lines* than *color highlighting* within each kind of retention task. Two-sample t-tests found no significant difference in compare (ordinal) ( $t = -0.647$ ,  $p = 0.524$ ), rank (ordinal) ( $t = -1.278$ ,  $p = 0.215$ ), or identify (numerical) ( $t = -1.442$ ,  $p = 0.156$ ) retention accuracy given the reduced sample size. Hence, *leader lines* impacted overall retention when compared to *color highlighting* (Factor #3), but showed no pattern of influence for specific kinds of tasks, whereas the benefit of *longform infographics* over *dynamic slideshows* (Factor #2) increased as the retention task grew in difficulty.

	Sample size	Compare (Ordinal)		Rank (Ordinal)		Identify (Numerical)		Total	
		Mean	SD	mean	SD	mean	SD	mean	SD
<i>Leader lines</i>	1,500	84.21%	15.69%	77.47%	15.49%	69.20%	14.38%	75.02%	15.98%
<i>Color highlighting</i>	1,500	80.07%	15.67%	69.99%	13.08%	63.23%	14.33%	69.13%	15.70%
<b>Total</b>	<b>3,000</b>	<b>82.14%</b>	<b>15.48%</b>	<b>73.72%</b>	<b>14.53%</b>	<b>66.22%</b>	<b>14.52%</b>	<b>72.08%</b>	<b>16.03%</b>
Differences		t-statistic	p value	t-statistic	p value	t-statistic	p value	t-statistic	p value
T-test results		-0.647	0.524	-1.278	0.215	-1.442	0.156	<b>6.060**</b>	<b>0.0262</b>

**Table 4.11: Participant Performance by Tropes.** Note: \*\* Two measures are significantly correlated at a two-tailed significance level of 0.05. Diverging color scheme: the darker the red indicates higher value; the darker the blue indicates a lower value, with white centered on 50%.

Trope design also impacted comprehension (Table 4.12). Overall, participants described 48.44% of the total topics when presented with *leader lines* and 47.56% when presented with *color highlighting*. A two-sample t-test on overall comprehension returned no statistical significance between trope designs ( $t = -0.607$ ,  $p = 0.560$ ). Moreover, a two-sample t-test resulted in no significant difference in the number of mistakes between trope designs ( $t = 0.295$ ,  $p = 0.591$ ). Interestingly, there was differential discussion of the tension. While nearly three-

quarters (73.60%) of participants discussed the tension when viewing stories with *leader lines*, only 64.80% of participants discussed the tension when viewing stories with *color highlighting*.

A two-sample t-test found this difference significant at  $\alpha=0.05$  ( $t = -3.667$ ,  $p = 0.035$ ). This is an interesting result, as the focus attention solution was applied to the protagonist and antagonist in many panels. Therefore, *leader lines* helped readers compare key characters (i.e., understand the tension) in the story better than *color highlighting*. Accordingly, when drawing attention to places or regions as characters, it is recommended to use leader lines instead of high contrast color. Using leader lines and text annotations is more effective for pointing out the tension of a story than using visuals to just highlight the result.

	Sample size	Problem	Tension	Protagonist	Antagonist	Effect/resolution	Cause	Space	Cliffhanger	Time	Total	Mistake/confusion
<i>Leader lines</i>	125	95.20%	73.60%	60.80%	52.00%	50.40%	35.20%	24.00%	25.60%	19.20%	48.44%	13.60%
<i>Color highlighting</i>	125	96.80%	64.80%	58.40%	52.80%	51.20%	29.60%	29.60%	28.00%	16.80%	47.56%	11.20%
<b>Total</b>	<b>250</b>	<b>96.00%</b>	<b>69.20%</b>	<b>59.60%</b>	<b>52.40%</b>	<b>50.80%</b>	<b>32.40%</b>	<b>26.80%</b>	<b>26.80%</b>	<b>18.00%</b>	<b>47.99%</b>	<b>12.39%</b>
<i>Difference</i>		t p	t p	t p	t p	t p	t p	T p	t p	t p	t p	t p
<i>T-test</i>		0.480 0.664	-3.667** 0.035	-0.389 0.724	0.299 0.789	0.098 0.928	-0.819 0.473	3.656** 0.035	0.454 0.581	-0.417 0.744	-0.607 0.560	0.295 0.591

**Table 4.12: Comprehension by Tropes.** Note: \*\* Two measures are significantly correlated at a two-tailed significance level of 0.05. Diverging color scheme: the darker the red indicates higher value; the darker the blue indicates a lower value, with white centered on 50%.

Another comprehension category with differential discussion was space. Interestingly, 29.60% of participants interpreted space correctly viewing stories with *color highlighting*, with only 24.00% of participants discussed space with viewing stories with *leader lines*. A two-sample t-test found this difference significant at  $\alpha=0.05$  ( $t = 3.656$ ,  $p = 0.035$ ). This is the only code on which the *leader lines* condition substantially outperformed the *color highlighting* condition. However, given the above discussion about the relationships of discussion of space to

characters, it is possible this increase was observed because the *leader lines* condition did not properly focus attention away from the overall geographic context and towards specific characters. Thus, this finding therefore more likely suggests that *leader lines* were the superior tropes design.

There were no significant differences in preferences between the trope conditions (Table 4.13). The largest difference in preference between trope designs regarded participant interest, with participants overall more interested in stories using *color highlighting* (interest; 5.2/7.0) rather than *leader lines* (interest; 4.8/7.0). A Mann-Whitney U test found no statistical difference in interest ( $w = 13$ ,  $p = 0.2$ ). Therefore, while trope design significantly impacted retention and comprehension, the difference did not register affectively across participants.

Sample size		Interest: The visual story interested me		Agreement: I agree with the visual story		Concern: The visual story concerned me		Enjoyment: I enjoyed the visual story		Influence: The visual story did not influence my beliefs about topic		Excitement: The visual story excited me.		Upsetting: I was upset by visual story		Boredom: The visual story bored me.	
		mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
<i>Leader lines</i>	1,000	4.8	1.7	4.9	1.5	4.3	1.9	4.2	1.8	3.9	1.9	3.4	1.6	3.1	1.8	3.2	1.9
<i>Color highlighting</i>	1,000	5.2	1.7	5.1	1.6	4.6	1.8	4.5	1.7	3.6	1.9	3.6	1.7	3.2	1.9	2.9	1.8
<b>Total</b>	<b>2,000</b>	<b>5.0</b>	<b>1.7</b>	<b>5.0</b>	<b>1.6</b>	<b>4.5</b>	<b>1.9</b>	<b>4.4</b>	<b>1.8</b>	<b>3.8</b>	<b>1.9</b>	<b>3.5</b>	<b>1.7</b>	<b>3.2</b>	<b>1.8</b>	<b>3.1</b>	<b>1.9</b>
Mann-Whitney U test		W		P		W		P		W		P		W		P	
Statistic results		13	0.2	10.5	0.561	9.5	0.772	11.5	0.384	6	0.66	10.5	0.552	10	0.663	9	0.902

**Table 4.13: Participant Preference by Tropes. Diverging color scheme centered on 4.0: the darker the red indicates higher value; the darker the blue indicates a lower value.**

In the exit survey, participants overall rated that they liked the use of *leader lines* (5.3/7.0) over *color highlighting* (5.1/7.0), although the layout was rated higher than both (5.4/7.0) (Table 4.14). Thus, *focus attention* is a visual storytelling trope that designers can apply

without impacting the overall look and feel of the map. Further, these results demonstrate the value of following visual storytelling tropes during design, as a subtle (to participants) differences in *focus attention* solutions yielded significant improvement in retention and comprehension of the visual story.

Trope preference	I liked the use of thick black outlines to emphasize important content.	I didn't notice the use of thick black outlines to emphasize important content	I liked the use of annotations with connecting lines to emphasize important content	I didn't notice the use of annotations with connecting lines to emphasize important content	I liked how the layout of text, maps, and graphics emphasized important content.	I didn't notice how the layout of text, maps, and graphics emphasized important content.
Total	5.1	2.7	5.3	2.5	5.4	2.4

**Table 4.14: Trope Preference.** Diverging color scheme centered on 4.0: the darker the red indicates higher value; the darker the blue indicates a lower value.

#### 4.5 Individual Differences (RQ #4)

Finally, I examined variation in retention, comprehension, and preference across individual differences. The exit survey collected several measures of individual differences, including education, expertise, familiarity, motivation, ability, and beliefs/bias. Figure 3.1 in Chapter 3 provides a breakdown of the sample by these categories. Dependence of retention and comprehension on individual differences was examined using Spearman's rank correlation tests (Table 4.15).

Regarding retention, the relationship of individuals to technology and design was a stronger driver than their relationship to the story theme. In particular, participants with a familiarity with ( $\rho = 0.207$ ,  $p = 0.021$ ) or interest in ( $\rho = 0.231$ ,  $p = 0.010$ ) the Internet significantly retained more information from the visual stories. This signals a potential confounder to performance, as differential familiarity with and interest in the online survey mechanism may have impact results, with participants unfamiliar or disinterested retaining less due to the online format. Interest in online news sources ( $\rho = 0.169$ ,  $p = 0.060$ ) and information

graphics ( $\rho = 0.172$ ,  $p = 0.055$ ) also exhibited a significant positive correlation with retention, suggesting increased motivation about the visual design prompted better attention to and ultimately retention about the stories. With information becoming more visual through a growing range of screen devices, use of the visual format may be a way to better engage young people and technologists in journalism.

In contrast, the relationship of individuals to the story theme was a stronger driver of comprehension than their relationship to technology. Increased training ( $\rho = -0.186$ ,  $p = 0.038$ ) negatively correlated with the *sea-level rise* theme, suggesting that participants with some education in environment and science topics actually gleaned less from the visual stories, instead relying on their prior background rather than drawing from specific evidence in the story. This is an important finding, as non-trained, non-experts actually may actually approach news (and new information generally) more objectively. It is arguable, however, that the subjectivity exhibited by experts may be appropriate, hard-earned subjectivity. Individual beliefs had an opposite effect, with individuals who were environmentally agnostic more likely to have poor comprehension about the *sea-level rise* story ( $\rho = -0.185$ ,  $p = 0.038$ ). Thus, getting people to care—perhaps by motivating through new technology and visual designs, as stated above—can be essential to getting people to understand, not vice versa. It is important to note that significant correlations were not found for the *presidential campaign donations* story, indicating that these findings are not universal to all story themes.

		Retention		Comprehension	
<i>Individual differences</i>		<i>Sea-level rise</i>	<i>Presidential campaign donations</i>	<i>Sea-level rise</i>	<i>Presidential campaign donations</i>
Familiarity	Environment and Science	-0.024		-0.101	
	Domestic Politics		0.135		-0.004
Training	Environment and Science	-0.049		-0.186**	
	Domestic Politics		-0.126		0.002
Interest	Environment and Science	0.042		-0.143	
	Domestic Politics		0.062		0.075
Beliefs/ bias	Socially liberal-v-conservative		0.011		-0.084
	Fiscally liberal-v-conservative		0.062		-0.023
	Environmentally conscious-v-agnostic	-0.070		-0.185**	
	Politically active-v-agnostic		-0.010		-0.034
	Concern about sea-level rise	-0.034		0.005	
	Concern about coastal vulnerable properties	-0.032		0.005	
	Concern about presidential campaign donations		0.079		-0.011
	Concern about the presidential election results		0.098		0.004
	I believe sea-level rise is a topic worth discussing	0.098		0.157	
	I believe presidential campaign donation is a topic worth discussing		0.159		0.110
	I believe sea-level rise is a problem	-0.020		0.102	
	I believe presidential election donation is a problem		0.150		0.006
		Overall retention		Overall comprehension	
Familiarity	Print News Sources	0.021		-0.164*	
	Online News Sources	-0.008		-0.035	
	Maps	0.034		0.005	
	Computing Technology	0.080		-0.083	
	The Internet	0.207**		0.107	
	Information Graphics	0.112		-0.060	
Training	Print News Sources	-0.111		-0.031	
	Online News Sources	-0.088		0.040	
	Maps	-0.094		-0.020	
	Computing Technology	-0.055		-0.038	
	The Internet	-0.008		0.037	
	Information Graphics	-0.063		-0.066	
Interest	Print News Sources	-0.100		-0.140	
	Online News Sources	0.169*		0.079	
	Maps	0.033		-0.075	
	Computing Technology	0.105		-0.033	
	The Internet	0.231**		0.060	
	Information Graphics	0.172*		-0.096	
Education	Education Level	-0.083		-0.084	

**Table 4.15: Individual Differences with Retention and Comprehension.** Note: \*\* two measures are significantly correlated at a two-tailed significance level of 0.05. \* two measures are significantly correlated at a two-tailed significance level of 0.1. Diverging color scheme centered on 0: the darker the red indicates higher value; the darker the blue indicates a lower value.

Whereas the genres (Factor #2) and tropes (Factor #3) more heavily influenced retention and comprehension—with some variability by individual differences—it was clear that individual differences regarding the story theme drove participant preference (Table 4.16). There were several broad patterns between individual differences and story preferences worth discussing. Personal concern for and value in a topic lead to stimulated core affect as well as increased interest in, concern for, and agreement with the story (Table 4.16A). These relationships exhibited many of the strongest positive correlations by individual difference. However, “concern about presidential election results” was the one Likert scale that did not follow this trend, again perhaps signaling the polarizing nature of the recent 2016 election and a feeling of helplessness over the outcome (Table 4.16B). Personal interest in the technology and visual design had a weaker, yet still significant impact on core affect and interest in, concern for, and agreement with the story (Table 4.16C). Finally, individual difference negatively correlated with keeping beliefs (on an inverted negative scale): participants with stronger beliefs and interests going into the study were more likely to shift their beliefs or interests after reviewing the stories (Table 4.16D). This is an exciting finding as it indicates a potential of visual storytelling in persuasion and rhetoric.



									D The visual story/stories did not influence my beliefs about sea-level rise or presidential election donations
		The visual story/stories excited me	The visual story/stories bored me	I enjoyed the visual story/stories	I was upset by visual story/stories	The visual story/stories interested me	The visual story/stories concerned me	I agree with the visual story/stories	
Familiarity	Environment and science	0.238**	-0.114	0.132	0.056	0.161	0.172**	0.231**	0.071
	Domestic Politics	0.192**	-0.151	0.192**	0.031	0.155	0.001	-0.032	0.024
Training	Environment and science	0.312**	0.038	0.158	0.178	0.034	0.075	0.071	0.154
	Domestic Politics	0.351**	-0.089	0.208**	0.175*	0.171	0.177**	0.021	-0.024
Interest	Environment and science	0.260	-0.179	0.149	0.140	0.182	0.272	0.305	-0.030
	Domestic Politics	0.218	-0.275	0.247	0.221	0.219	0.188	0.013	-0.087
Beliefs/ bias	Socially liberal-v-conservative	-0.102	0.164*	0.008	-0.098	-0.081	-0.147	-0.039	0.129
	Fiscally liberal-v-conservative	-0.067	0.066	0.103	-0.024	0.027	-0.028	0.031	0.034
	Environmentally conscious v-agnostic	-0.270**	0.276**	-0.091	-0.238**	0.214**	-0.327**	-0.358**	0.184**
	Politically active-v-agnostic	-0.149	0.340**	-0.116	0.102	-0.207**	-0.032	0.049	0.083
	Concern about sea-level rise	0.294**	-0.292**	0.320**	0.319**	0.492**	0.551**	0.635**	-0.399**
	Concern about coastal vulnerable properties	0.382**	-0.348**	0.389**	0.304**	0.486**	0.573**	0.619**	-0.368**
	Concern about presidential campaign donations	0.267**	-0.257**	0.313**	0.329**	0.384**	0.396**	0.423**	-0.177**
	Concern about the presidential election results	0.043	-0.163	0.117	0.118	0.179	0.198**	0.155	-0.159
	I think sea-level rise is a topic worth discussing	0.256**	-0.502**	0.325**	0.226**	0.518**	0.533**	0.634**	-0.417**
	I think presidential donations is a topic worth discussing	0.081	-0.339**	0.288**	0.229**	0.342**	0.337**	0.330**	-0.212**
	I believe sea-level rise is a problem	0.244*	-0.332**	0.281**	0.309**	0.475**	0.527**	0.649**	-0.389**
	I believe presidential election donations are problems	0.075	-0.331**	0.212	0.174	0.290**	0.327**	0.368**	-0.257**
Familiarity	Print News Sources	0.038	-0.061	0.078	0.107	0.155	0.090	0.087	-0.020
	Online News Sources	0.002	-0.089	0.137	0.083	0.178**	0.033	0.258**	-0.025
	Maps	-0.218*	-0.056	-0.044	0.108	0.089	0.104	0.052	-0.003
	Computing Technology	-0.090	0.022	-0.043	0.007	0.059	0.156*	0.117	-0.058
	The Internet	-0.247**	0.029	-0.150*	-0.071	-0.069	0.016	0.111	-0.137
	Information Graphics	0.106	-0.058	0.085	0.042	0.133	0.224**	0.245**	-0.225**
Training	Print News Sources	0.247**	0.038	0.098	0.110	0.106	0.136	0.056	0.052
	Online News Sources	0.244**	0.060	0.084	0.050	0.087	0.119	0.077	0.032
	Maps	0.278**	-0.051	0.168*	0.066	0.164	0.183**	0.138	-0.014
	Computing Technology	0.102	-0.009	0.129	0.069	0.197	0.277**	0.221**	-0.053
	The Internet	0.083	0.053	0.086	0.040	0.113	0.145	0.153**	0.006
	Information Graphics	0.275**	0.044	0.124	0.078	0.078	0.172*	0.107	0.016
Interest	Print News Sources	0.416**	-0.173*	0.288**	0.148	0.306**	0.225*	0.150*	-0.155
	Online News Sources	0.315**	-0.190*	0.342**	0.047	0.314**	0.226**	0.250**	-0.160*
	Maps	0.326**	-0.293**	0.390**	0.053	0.355**	0.185	0.246**	-0.158
	Computing Technology	0.026	-0.208**	0.099	-0.078	0.236**	0.224**	0.220**	-0.222**
	The Internet	-0.035	-0.136	0.098	-0.057	0.143	0.121	0.302**	-0.235**
	Information Graphics	0.390**	-0.223**	0.405**	0.009	0.295**	0.270**	0.204**	-0.219**
Education	Education Level	0.067	0.120	-0.026	0.092	-0.110	-0.036	-0.198**	0.062

**Table 4.16: Individual Differences with Story Preference.** Note: \*\* two measures are significantly correlated at a two-tailed significance level of 0.05. \* two measures are significantly correlated at a two-tailed significance level of 0.1. Diverging color scheme centered on 0: the darker the red indicates higher value; the darker the blue indicates a lower value.

## CHAPTER 5: CONCLUSION AND FUTURE DIRECTIONS

### 5.1 Summary

This research sought to discover the influences of map-based visual storytelling design on reading retention, comprehension, preference, and, through this exploration, identified best practices in designing effective map-based visual stories.

1. *Can a linear, three-act narrative be effectively applied to map-based visual storytelling? Three-Act Narrative (RQ #1).* Yes! The utility of a three-act narrative for visual storytelling was confirmed primarily through participant responses to the comprehension open-ended question. Participant comprehension overall was better than expected across visual story designs, and mistakes and confusions were relatively infrequent, demonstrating that the general public can understand and interpret visual stories following a three-act narrative. Hence, visual stories do not need to be sensational or exaggerated to be effective: they just need to have a coherent linear structure (genre) and focus attention to important story elements (tropes). Participants focused more on the problem in their comprehension responses than other story elements of the three-act narrative, indicating that the problem is the most salient part of a visual story and should be included in the title and redundantly emphasized throughout the story. Finally, the protagonist and antagonist also were discussed with comparatively high frequency, suggesting a major way that visual storytelling is different from traditional map design: it is character-driven, providing partial treatment of specific places of importance rather than broad patterns.
2. *What is the influence of visual storytelling genres on the retention, comprehension, and preference of the story? (RQ #2)* The story genre significantly influenced both

retention and comprehension, but not preference. Participants had better retention and comprehension when the visual stories were presented as *longform infographics* instead of *dynamic slideshows*. Regarding retention, the advantage of *longform infographics* was particularly important for recalling numerical information (numerical identification tasks). Regarding comprehension, a small set of participants missed the essential problem of the story when viewing *dynamic slideshows*. This is the worst of both worlds, with *dynamic slideshows* causing participants to forget specific facts *and*, to a lesser degree, miss the overall point. The poorer performance with *dynamic* slideshows likely is attributed to the manner by which the genre enforces linearity and doses information, as *longform infographics* enabled scrolling at a user-controlled pace, whereas *dynamic slideshows* dosed information in a designer-controlled pace. The *dynamic slideshows* are further susceptible to bandwidth issues through multiple loads. This finding confirms that selecting a storytelling genre described by Segel & Heer (2010) and Roth (2016) is a nontrivial design decision, warranting additional research. This finding also calls into question the optimal manner for dosing information in both research and teaching, given that material commonly is presented as a slideshow.

3. *What is the influence of visual storytelling tropes on retention, comprehension, and preference of the story? (RQ #3)* As with genres, the focus attention strategies (one visual storytelling trope) significantly influenced both retention and comprehension, but not preference. Participants had better retention and comprehension when story elements were accented using *leader lines* instead of *color highlighting*. This finding is consistent with Griffin and Robinson 's (2015) recommendations for using leader

lines over other forms of coordinating highlighting in the context of exploratory geovisualization. While there was no difference in understanding the problem between trope conditions, unlike the storytelling genres, the major difference in comprehension between focus attention strategies was in understanding the tension, an essential story element in character-driven visual storytelling. Interestingly, there was no difference in preference between the two trope conditions, showing that subtle deviations from traditional cartographic design following visual storytelling tropes can have a positive improvement in performance without impacting subjective satisfaction with the design.

4. *What is the influence of individual differences of the reader on retention, comprehension, and preference of the story? (RQ #4)* Whereas the genre and trope designs heavily influenced retention and comprehension—with some variability by individual differences—it was clear that individual differences regarding the story theme drove participant preference. The amount of familiarity or interest in web technology positively influenced retention, whereas prior training in the domain topic negatively influenced comprehension, as experts included more outside knowledge not part of the visual story into their comprehension responses. Finally, personal concern for the topic drove preference. Personal concern for the topic stimulated core affect and increased self-reported interest in, concern for, and agreement with the story. Finally, participants with stronger beliefs and interests about the theme prior to reading the visual story were more likely to shift their beliefs or interests after reviewing the stories. This is an exciting finding as it indicates a potential of visual storytelling in persuasion and rhetoric.

## 5.2 Limitations and Future Directions

There are several limitations to the study design worth noting, as they may impact the research in map-based visual storytelling effectiveness. One of the limitations is the story theme. Choosing presidential campaign donations as one of the story themes may have impacted results, as the online survey was administered only 4 months after the 2016 presidential election.

A second limitation was the number of tested genre and trope conditions. In this research, I only tested two genres and two tropes, a necessary simplification of the study design. *Dynamic slideshows* and *longform infographics* were selected because they are informationally equivalent, with both reduced to a consistent set of panels, and therefore comparable for balanced factorial study design. Other genres like narrated animations or personalized story maps are more complicated for a comparison, and therefore present different challenges for empirical research but also different opportunities for cartographic design. Moreover, I only compared two focus attention strategies, and did not vary other visual storytelling tropes outlined by Roth (2016). Other tropes not included in the study should be tested in the future.

The final major limitation of this project was the design control imposed across the visual stories. For testing the impact of story genres and tropes, stories were with limited visual designs. Color palettes and layouts were constrained for comparison and consistency. However, in real storytelling situations, visuals are various and their impacts on retention, comprehension, and preference will be large and complicated. Future research is needed to evaluate the impact of actual visual stories from new media in a realistic setting with realistic cartographer and user goals.

This research revealed many directions for future research. First, future research is needed to understand the value of alternative visual storytelling genres. In particular, visual

stories with different relative amounts of text and graphics need to be evaluated to find the relevant influence of each component on the effectiveness and preference of a visual story. Further, combinations of basic genres should be explored to determine if there is a payoff with combination, much like redundant symbolization in traditional cartographic design.

A second area of future research is testing alternative tropes as well as different focus attention solutions. In this study, I tested the impacts of black *leader lines* and black *color highlighting*. Falling in line with the important setting the mood trope, more colors could be tested, for example, red and yellow colors are usually considered as eye-catching, and they might have different impacts on preference and core affect compared to black. Other design strategies of focus attention like call-outs, opacity masks, and dynamic zooming also should be tested. Further study could test more tropes' impacts on visual story reading, and their combinations' impacts, as in real storytelling design scenario, a story might include more than one tropes. Will a combination of story tropes have an advantage over design for a story trope? Do different tropes influence different aspects of visual storytelling retention, comprehension, and preference?

Third, this study only tested the effectiveness of visual storytelling when participants read the stories passively by themselves. Interactivity was constrained to common browser controls. How would interactivity, animation, and dynamic updates influence retention, comprehension, and preference? Would inclusion of social media features, such as amplifying through "Likes" or adding commentary, further influence engagement? Finally, do the results translate to live or video presentations narrated by a person? How well does this hold in research versus pedagogical settings?

### 5.3 Design Recommendations

This study generated new insight about the design for map-based visual stories relevant to cartographers and data journalists. The following set of visual story design considerations were collected from the results during the experiment:

- *Design stories with a three-act narrative structure to enforce linearity:* A three-act narrative provides a consistent linear structure across themes and designs, and it is effective in retention and comprehension of story reading. Within the structure, emphasize the problem as it is the most salient component of the story. Coax out place-based characters that exemplify a prototypical protagonist and antagonist.
- *Consider designing story in longform infographics:* While not as popular in practice as other genres, the *longform infographics* has a clear place in visual storytelling. When the story content is linear, the story contains a large amount of numerical information, or the experience does not require interactivity, consider *longform infographics* over alternative genres.
- *Build dynamic slideshows more effectively:* Slideshows are a common storytelling medium, but they can be better. When using *dynamic slideshows*: (1) provide progress affordances so users could have a sense of how far they have already viewed within the whole story; (2) make each panel on a fixed position on the page so that the user does not need to scroll when viewing a new slide, and (3) keep the size of the graphics small to overcome bandwidth lags.
- *Consider using leader lines for emphasizing important information:* Use *leader lines* instead of color or other visual variables when applying focus attention in visual stories, as *leader lines* are more visually salient and improve retention and comprehension. As

with traditional cartographic design, *leader lines* should be used sparingly, only on the most important story elements.

- *Spark readers' interests:* New media and new visual storytelling forms capture the interest of readers, when designed effectively. Continue to explore new genres and tropes to further engage your readership.

#### ***5.4 Significance***

Compared to its increasing popularity, research in map-based visual storytelling is relatively limited. The research reported here fills an important gap, but is just one step towards fully realizing cartographic design as visual storytelling. Continued research is needed to understand how visual stories work to improve design and practice. There are so many important stories to tell (and see)!



## REFERENCES

- Aksoy, C., & Bayar, Z. (2016). Archaeological Ethnography of the Battle of Aslıhanlar (29–30 August 1922): A Case Study of Public Archaeology, Visual Storytelling, and Interactive Map Design. *European Journal of Archaeology*, 19(1), 68-94.
- Brown, L. A. (1979). *The story of maps*. Courier Corporation.
- Çöltekin, A., Heil, B., Garlandini, S., & Fabrikant, S. I. (2009). Evaluating the effectiveness of interactive map interface designs: a case study integrating usability metrics with eye-movement analysis. *Cartography and Geographic Information Science*, 36(1), 5-17.
- Cairo, A. (2012). *The Functional Art: An introduction to information graphics and visualization*. New Riders.
- Caquard, S. (2013). Cartography I: Mapping narrative cartography. *Progress in Human Geography*, 37(1), 135-144.
- Caquard, S., & Cartwright, W. (2014). Narrative cartography: From mapping stories to the narrative of maps and mapping.
- Caudle, S. L. (2004). Qualitative data analysis. *Handbook of practical program evaluation*, 2(1), 417-438.
- Cartwright, W. (1997). New media and their application to the production of map products. *Computers & Geosciences*, 23(4), 447-456.
- Cartwright, W., & Field, K. (2015) Exploring cartographic storytelling. Reflections on mapping real-life and fictional stories.
- Cohen, G. L. (2012). Identity, belief, and bias. *Ideology, psychology, and law*, 385-403.
- Crampton, J. W. (2009). Cartography: maps 2.0. *Progress in Human Geography*, 33(1), 91-100.
- Denil, M., 2011. the search for a radical cartography. *Cartographic Perspectives*, (68), pp.7-28.
- Figueiras, A. (2014, July). How to tell stories using visualization. In *Information Visualisation (IV), 2014 18th International Conference on* (pp. 18-18). IEEE.
- Gershon, N., & Page, W. (2001). What storytelling can do for information visualization. *Communications of the ACM*, 44(8), 31-37.
- Gray, J., Chambers, L., & Bounegru, L. (2012). *The data journalism handbook: how journalists can use data to improve the news*. " O'Reilly Media, Inc."
- Griffin, A. L., & McQuoid, J. (2012). At the intersection of maps and emotion: The challenge of spatially representing experience. *Kartographische Nachrichten*, 62(6), 291-299.

- Griffin, A. L., & Robinson, A. C. (2015). Comparing color and leader lines highlighting strategies in coordinated view geovisualizations. *IEEE transactions on visualization and computer graphics*, 21(3), 339-349.
- Haft, A. J. (2011). Introduction to Maps and Mapping in Kenneth Slessor's poetic sequence *The Atlas*. *Cartographic Perspectives*, (70), 5-43.
- Haklay, M., Singleton, A., & Parker, C. (2008). Web mapping 2.0: The neogeography of the GeoWeb. *Geography Compass*, 2(6), 2011-2039.
- Hsieh, H. F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative health research*, 15(9), 1277-1288.
- Kosara, R., & Mackinlay, J. (2013). Storytelling: The next step for visualization. *Computer*, 46(5), 44-50.
- Lidwell, W., Holden, K., & Butler, J. (2010). *Universal principles of design, revised and updated: 125 ways to enhance usability, influence perception, increase appeal, make better design decisions, and teach through design*. Rockport Pub.
- Monmonier, M. (1989). *Maps with the news: The development of American journalistic cartography*. University of Chicago Press.
- Montello, D., & Sutton, P. (2006). *An introduction to scientific research methods in geography*. Sage.
- Muehlenhaus, I. (2013). The design and composition of persuasive maps. *Cartography and Geographic Information Science*, 40(5), 401-414.
- Muehlenhaus, I. (2014). Going Viral: The Look of Online Persuasive Maps. *Cartographica: The International Journal for Geographic Information and Geovisualization*, 49(1), 18-34.
- Norman, G. (2010). Likert scales, levels of measurement and the "laws" of statistics. *Advances in health sciences education*, 15(5), 625-632.
- Pearce, M. W. (2008). Framing the days: place and narrative in cartography. *Cartography and geographic information science*, 35(1), 17-32.
- Pearce, M. W., & Hermann, M. J. (2010). Mapping Champlain's travels: restorative techniques for historical cartography. *Cartographica: The International Journal for Geographic Information and Geovisualization*, 45(1), 32-46.
- Robinson, A. C., Kerski, J., Long, E. C., Luo, H., DiBiase, D., & Lee, A. (2015). Maps and the geospatial revolution: teaching a massive open online course (MOOC) in geography. *Journal of Geography in Higher Education*, 39(1), 65-82.
- Robinson, A. C. (2011). Highlighting in geovisualization. *Cartography and Geographic Information Science*, 38(4), 373-383.

- Rogers, S. (2014). Data journalism is the new punk. *British Journalism Review*, 25(2), 31-34.
- Roth, R. E., & Harrower, M. (2008). Addressing map interface usability: Learning from the lakeshore nature preserve interactive map. *Cartographic Perspectives*, (60), 46-66.
- Roth, R. E. (2009). The impact of user expertise on geographic risk assessment under uncertain conditions. *Cartography and Geographic Information Science*, 36(1), 29-43.
- Roth, R. E. (2013). Interactive maps: What we know and what we need to know. *Journal of Spatial Information Science*, 2013(6), 59-115.
- Roth, R. E. (2015). Interactivity and cartography: a contemporary perspective on user interface and user experience design from geospatial professionals. *Cartographica: The International Journal for Geographic Information and Geovisualization*, 50(2), 94-115.
- Roth, R. E. (2016). Cartographic Design as Visual Storytelling. *2016 Annual Meeting of the American Association of Geographers*.
- Segel, E., & Heer, J. (2010). Narrative visualization: Telling stories with data. *IEEE transactions on visualization and computer graphics*, 16(6), 1139-1148.
- Slocum, T. A., Blok, C., Jiang, B., Koussoulakou, A., Montello, D. R., Fuhrmann, S., & Hedley, N. R. (2001). Cognitive and usability issues in geovisualization. *Cartography and Geographic Information Science*, 28(1), 61-75.
- Smith, S., & Watson, J. (2010). *Reading autobiography: A guide for interpreting life narratives*. U of Minnesota Press.
- Sparke, M. (1998). A map that roared and an original atlas: Canada, cartography, and the narration of nation. *Annals of the Association of American Geographers*, 88(3), 463-495.
- Sweeney, M., Maguire, M., & Shackel, B. (1993). Evaluating user-computer interaction: a framework. *International journal of man-machine studies*, 38(4), 689-711.
- Vujaković, P. (2014). The State as a 'Power Container': The Role of News Media Cartography in Contemporary Geopolitical Discourse. *The Cartographic Journal*, 51(1), 11-24.
- Weber, W., & Rall, H. (2012, July). Data visualization in online journalism and its implications for the production process. In *Information Visualisation (IV), 2012 16th International Conference on* (pp. 349-356). IEEE.
- Wood, D., & Fels, J. (1992). *The power of maps*. Guilford Press.

## WEB RESOURCES REFERENCE:

- Young, D. (2012, October 23), Telling a good story: impact case studies as narrative arc. Retrieved from

<https://research.northumbria.ac.uk/support/2012/10/23/telling-a-good-story-impact-case-studies-as-narrative-arc/>

Chart: One Year of Prison Costs More Than One Year at Princeton. (2011, November 1). The Atlantic Retrieved from <http://www.theatlantic.com/national/archive/2011/11/chart-one-year-of-prison-costs-more-than-one-year-at-princeton/247629/>

Branch, J. et al. (2012, February). Snow Fall. New York Times. Retrieved from <http://www.nytimes.com/projects/2012/snow-fall/#/?part=tunnel-creek>

Amazonia Under Threat. (2015). National Geographic. Retrieved from <http://www.nationalgeographic.com/climate-change/explore-amazonia/#/>

Cai & Granados (2016, January 24). Snowzilla is done with us, but now the shoveling begins. The Washington Post. Retrieved from [https://www.washingtonpost.com/local/one-of-the-biggest-storms-in-regions-history-brings-washington-to-standstill/2016/01/24/53f10b28-c283-11e5-a4aa-f25866ba0dc6\\_story.html?utm\\_term=.524df0562b9f](https://www.washingtonpost.com/local/one-of-the-biggest-storms-in-regions-history-brings-washington-to-standstill/2016/01/24/53f10b28-c283-11e5-a4aa-f25866ba0dc6_story.html?utm_term=.524df0562b9f)

Lavin (2011, January/ February). How the Recession Changed Us. The Atlantic. Retrieved from <https://www.theatlantic.com/magazine/archive/2011/01/how-the-recession-changed-us/308347/>

Assessing the Damage and Destruction in Gaza (2014, August 15). New York Times. Retrieved from [https://www.nytimes.com/interactive/2014/08/03/world/middleeast/assessing-the-damage-and-destruction-in-gaza.html?\\_r=0](https://www.nytimes.com/interactive/2014/08/03/world/middleeast/assessing-the-damage-and-destruction-in-gaza.html?_r=0)

Ukraine Crisis in Maps. (2014, September 5). New York Times. Retrieved from <https://www.nytimes.com/interactive/2014/02/27/world/europe/ukraine-divisions-crimea.html>

US base opponent wins Okinawa governor poll. (2014, November 17). BBC News. Retrieved from

<http://www.bbc.com/news/world-asia-30074445>

## APPENDICES:

### Appendix A

#### SOAKING IN WATER

Sea-Level Rise and Vulnerable Coastal Properties Since 2012



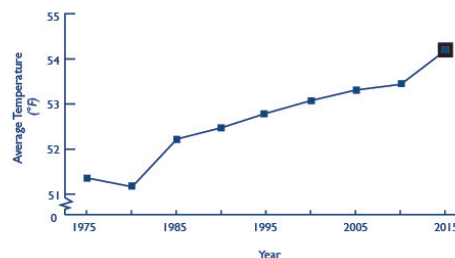
Even small rises in sea-level dramatically increase coastal vulnerability to storms

#### What is Happening with Our Coasts? It Starts with Rising Temperatures



U.S. average temperatures have increased almost 3°F in the past 40 years

U.S. average temperatures peaked at 54.3°F in 2015

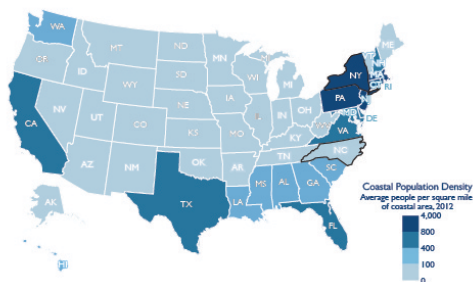


#### Why Do Coasts Matter?

More than 50% of U.S. Citizens Lived in Coastal Areas by 2012

3,081 people live in an average square mile of New York coasts

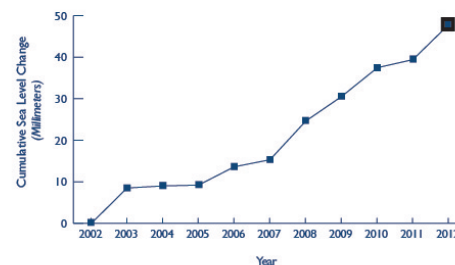
Only 73 people live in an average square mile of North Carolina coasts



#### So What? Rising Sea Levels Pose a Problem...

The U.S. average sea levels in 2012 reached 47.8 millimeters above the 2002 average

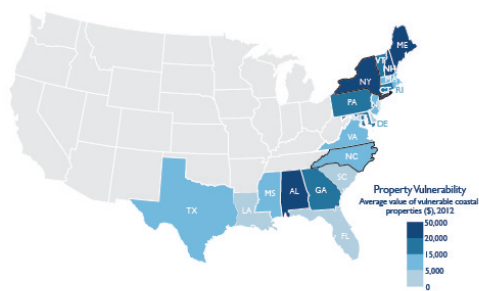
Global sea levels rose 8.4 millimeters in 2012, the largest sea level rise from 2002-2012



#### ...Particularly for States on the East Coast

The average value of vulnerable properties in coastal areas is \$24,800 in New York

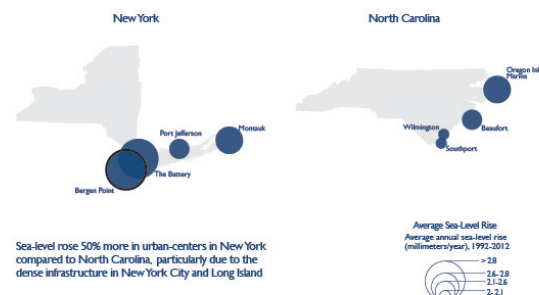
The average value of vulnerable properties in coastal areas is only \$7,730 in North Carolina



#### A Deeper Look:

##### Sea-Levels Rose the Most in Major Stations

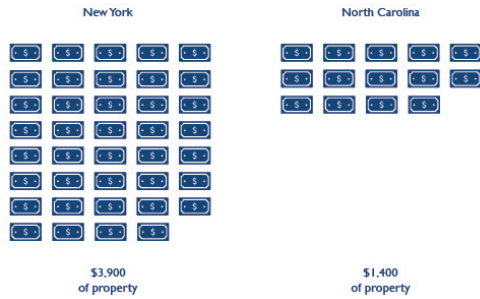
Sea-level rise annual rate in Bergen Point is 4.4 millimeters, the highest among stations in two states



Sea-level rose 50% more in urban-centers in New York compared to North Carolina, particularly due to the dense infrastructure in New York City and Long Island

### As a Result, Sea-level Rise Has a Different Impact on Vulnerability in Coastal States like New York versus North Carolina

Every inch in sea level rise exposes



### What's Next? New York and North Carolina Represent Different Alternatives for Addressing Sea-level Rise



New York has invested considerable public funds to prevent sea-level rise related crises

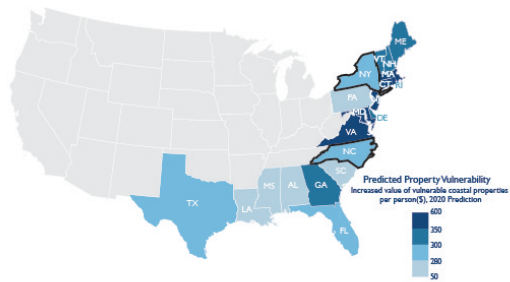


At the same time, North Carolina has failed to act on sea-level rise

### What Do You Think We Should Do As a Nation?

The value of vulnerable properties per person in New York only is predicted to increase to \$290 by 2020 if sea-levels continue to increase at a consistent rate

The value of vulnerable properties per person in North Carolina is predicted to increase a surprising \$325 by 2020 if sea-level continue to increase at a consistent rate



## Appendix B

## THE PRESIDENCY'S PRICE TAG

Campaign Donations and the 2012 Presidential Election

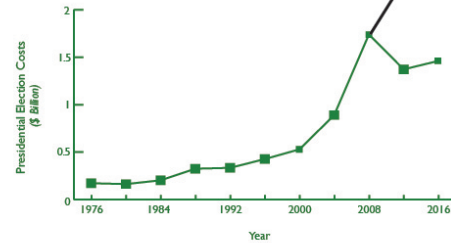


Private donations, not public discourse,  
shape the outcome of the Presidential Election

### What Is Happening with Our Elections? It Starts with Rising Campaign Costs

U.S. presidential campaign costs have increased nearly 800% in the past 40 years

Campaign costs peaked at \$1.74 billion in the 2008 presidential election

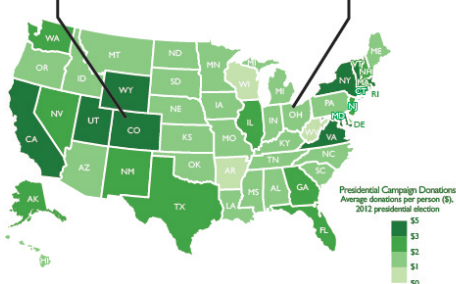


### Why Do Costs Matter?

#### More than 50% of Campaign Funds were from Donations in 2012

The average person in Colorado donated \$3.3 during the 2012 presidential election

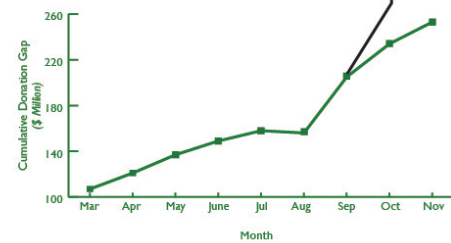
The average person in Ohio donated only \$1.5 during the 2012 presidential election



### So What? Increasing Donations Pose a Problem...

The Democrat advantage in campaign donations reached \$253 million for the 2012 presidential election

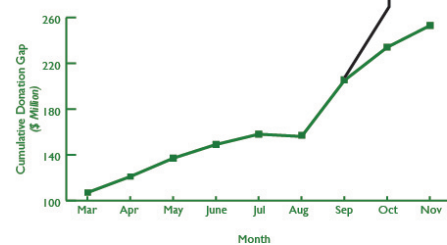
Democrats received \$51 million more donations than Republicans in September, the largest donations advantage during the 2012 presidential election



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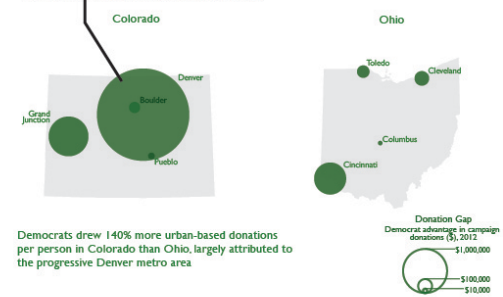
Democrats received \$51 million more donations than Republicans in September, the largest donations advantage during the 2012 presidential election



### A Deeper Look:

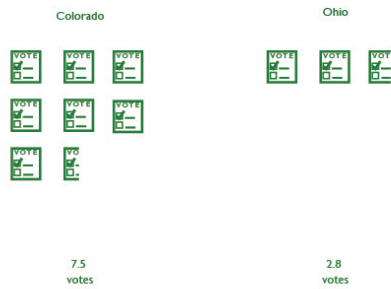
#### Democrats Gained their Largest Donation Advantage in Major Cities

The Democrat's gained an advantage of \$4,400,000 in Denver, the highest urban lead in swing states



### As a Result, Campaign Donations Have a Different Influence on Election Results in Swing States like Colorado versus Ohio

Every \$100 advantage for the Democrats bought



### What's Next? Colorado and Ohio Represent Different Alternatives for Addressing Campaign Donations

Colorado



Colorado has imposed new amendment to limit campaign funding since the 2012 presidential election

Ohio

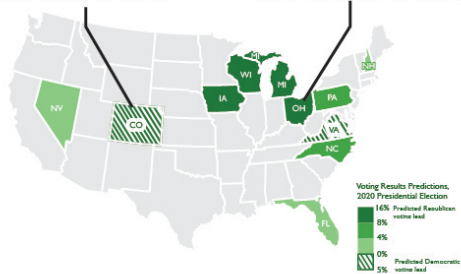


At the same time, Ohio has failed to act on campaign funding

### What Do You Think We Should Do As a Nation?

The Democrats are predicted to make only a 2.3% gain in Colorado in the 2020 presidential election if campaign funding remains consistent from 2016

The Republicans are predicted to make a whopping 12.5% gain in Ohio in the 2020 presidential election if campaign funding remains consistent from the 2016





## Appendix C

**THE PRESIDENCY'S PRICE TAG**

Campaign Donations and the 2012 Presidential Election

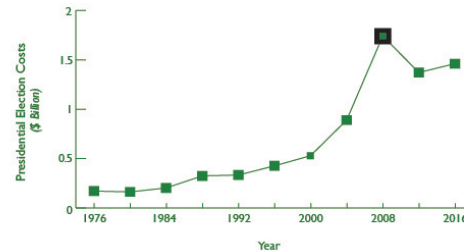


Private donations, not public discourse,  
shape the outcome of the Presidential Election

**What Is Happening with Our Elections?  
It Starts with Rising Campaign Costs**

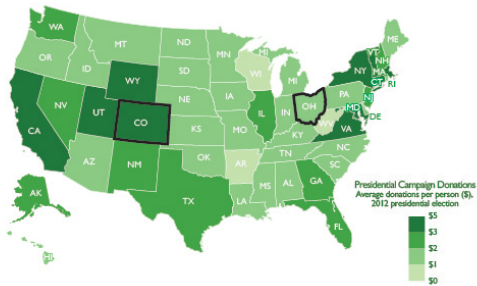
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**Why Do Costs Matter?  
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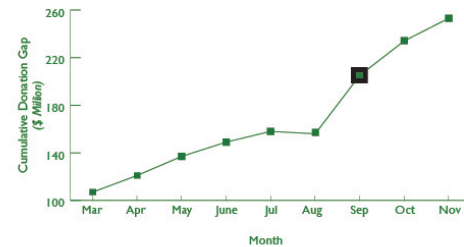
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The average person in Ohio donated only  
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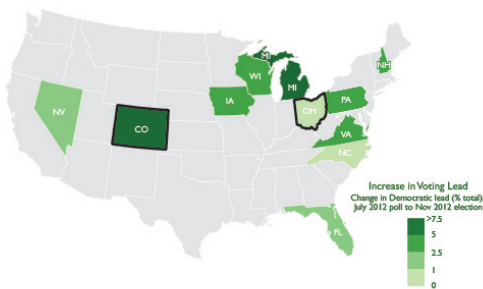
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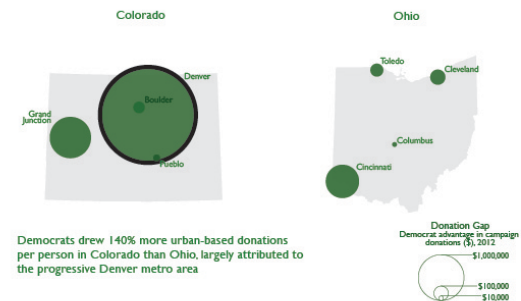
**...Particularly for Swing States**

Democrats increased their lead by 6.5%  
in the swing state of Colorado

Democrats only increased their lead  
by 0.7% in the swing state of Ohio

**A Deeper Look:  
Democrats Gained their Largest Donation Advantage in Major Cities**

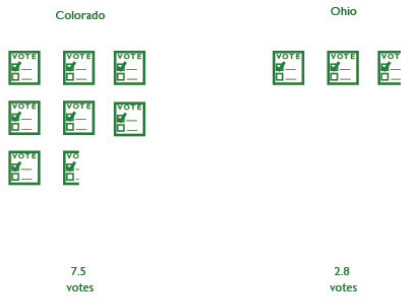
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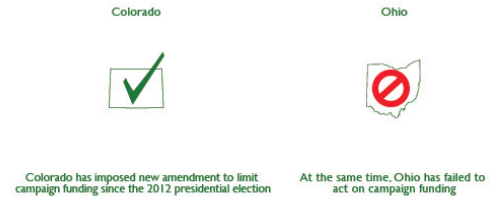
Democrats drew 140% more urban-based donations  
per person in Colorado than Ohio, largely attributed to  
the progressive Denver metro area

### As a Result, Campaign Donations Have a Different Influence on Election Results in Swing States like Colorado versus Ohio

Every \$100 advantage for the Democrats bought



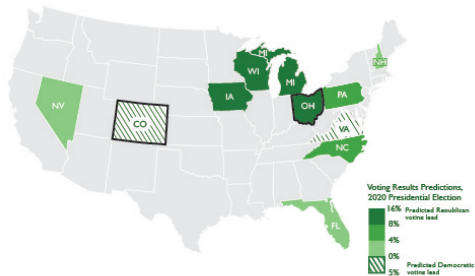
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## Appendix D

**SOAKING IN WATER**

Sea-Level Rise and Vulnerable Coastal Properties Since 2012

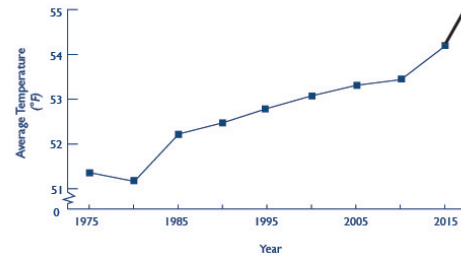


Even small rises in sea-level dramatically increase coastal vulnerability to storms

**What is Happening with Our Coasts?  
It Starts with Rising Temperatures**

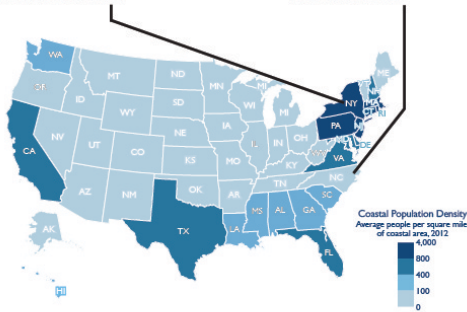
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**Why Do Coasts Matter?****More than 50% of U.S. Citizens Lived in Coastal Areas by 2012**

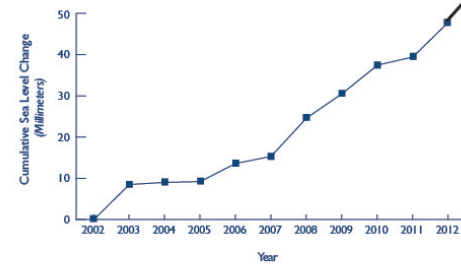
3,081 people live in an average square mile of New York coasts

Only 73 people live in an average square mile of North Carolina coasts

**So What? Rising Sea Levels Pose a Problem...**

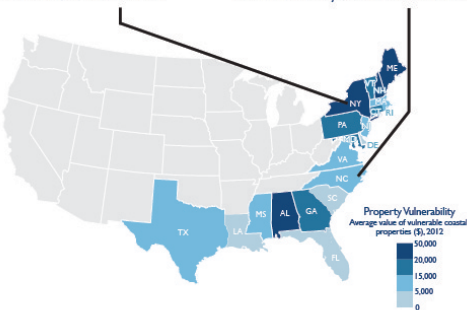
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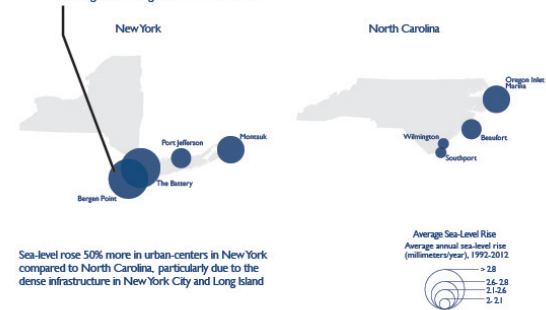
**...Particularly for States on the East Coast**

The average value of vulnerable properties in coastal areas is \$24,800 in New York

The average value of vulnerable properties in coastal areas is only \$7,730 in North Carolina

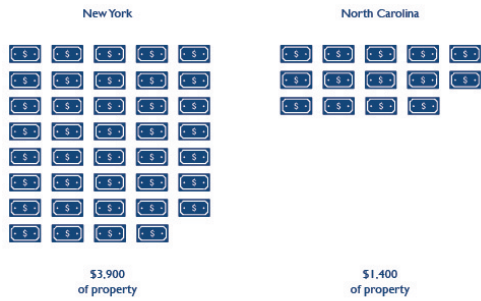
**A Deeper Look:****Sea-Levels Rose the Most in Major Stations**

Sea-level rise annual rate in Bergen Point is 4.4 millimeters, the highest among stations in two states



### As a Result, Sea-level Rise Has a Different Impact on Vulnerability in Coastal States like New York versus North Carolina

Every inch in sea level rise exposes



### What's Next? New York and North Carolina Represent Different Alternatives for Addressing Sea-level Rise



New York has invested considerable public funds to prevent sea-level rise related crises

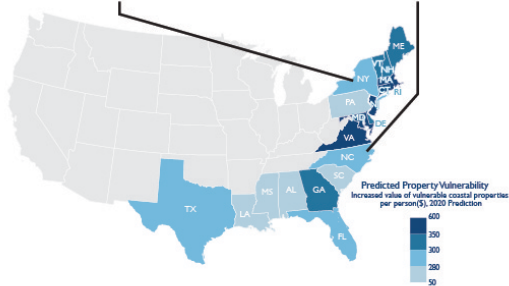


At the same time, North Carolina has failed to act on sea-level rise

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## Appendix E

### Map-based Visual Storytelling Survey Protocol

#### CONSENT

#### **Page #1: Welcome to the Study! Please Review the Following Information**

**Title of the Study:** Map-Based Visual Storytelling: An Assessment of Maps and Graphics in Online News Stories

**Principal Investigators:** Robert E. Roth  
550 N. Park Street  
Madison, WI 53706  
Email: reroth@wisc.edu

Zihan Song  
550 N. Park Street  
Madison, WI 53706  
Email: zsong57@wisc.edu

#### **DESCRIPTION OF THE RESEARCH**

You are invited to participate in a study aimed at improving the design of maps and graphics in online news stories.

#### **WHAT WILL MY PARTICIPATION INVOLVE?**

If you decide to participate in this research, you will complete an online survey requiring you to review a pair of news stories that include a combination of text, maps, and graphics. You will be asked questions about the stories after your review. The survey will take approximately 30 minutes to complete.

#### **ARE THERE ANY RISKS TO ME?**

Risk to participation is minimal. There are no foreseeable physical or mental risks to participation beyond those encountered in the normal course of everyday life.

#### **ARE THERE ANY BENEFITS TO ME?**

Your responses to the survey will be used to develop a better understanding of the design of news stories that include maps and graphics. You will be compensated \$4 for your participation. Compensation will only be awarded after you complete the study.

#### **HOW WILL MY CONFIDENTIALITY BE PROTECTED?**

While there will be publications as a result of this study, only group characteristics will be published. No personally identifiable information will be collected and maintained.

### **ELIGIBILITY**

- You must be 18 years of age or older.
- English must be your first language.
- You must currently be living in the United States.
- You must complete the survey on a laptop or desktop computer (i.e., **NOT** a mobile device such as a phone or tablet).

### **WHOM SHOULD I CONTACT IF I HAVE QUESTIONS?**

You may ask any questions about the research at any time. If you have questions about the research after you leave today, please contact Robert Roth (reroth@wisc.edu) or Zihan Song (zsong57@wisc.edu). If you are not satisfied with response of research team, have more questions, or want to talk with someone about your rights as a research participant, you should contact the Education Research and Social & Behavioral Science IRB Office at 608-263-2320.

Your participation is completely voluntary. If you decide not to participate or to withdraw from the study, it will not incur a penalty.

If you agree to take part in this research study as outlined above, please click “I agree” below:

[button] I understand my rights as a participant and agree to participate in this research study

[button] I do not agree to participate in this research study

## INSTRUCTIONS

**Page #2: Thank you for agreeing to participate! Please review the following instructions before taking the survey.**

Today, newspapers commonly release their news stories online in addition to their printed versions. These stories often have a geographic component (i.e., where the event took place), and increasingly include visuals such as maps or graphics to support the textual news descriptions. Stories that rely more on graphics than text are referred to as “visual” stories, and take many different forms on the internet. The following survey uses two case study visual stories to learn how to improve news reporting that relies on a combination of text, maps, and graphics.

### INSTRUCTIONS:

The survey proceeds in three sections:

1. First, you will be given an example story to familiarize yourself with the “visual” story form used in the study. You also will be given example questions to get a feel for the kinds of written and multiple choice questions you will need to answer about the visual stories.
2. You then will be presented with two different visual stories. You will review each visual story individually and respond to a set of questions about your comprehension, reaction, retention, and preference of the stories. Please review the visual story and complete the related questions using your **complete focus** (do not view other websites, split your attention, etc.). This survey relies on your feedback, so please take time in your responses.
3. After reviewing both visual stories, you will respond to a series of background questions about your interests and experiences. You will be compensated after you submit the background survey.

[button] I have reviewed the instructions and confirm I am eligible to participate in the study.

## TRAINING BLOCK

### Page #3: Training Example

Please review the following example about bookstores in the U.S. to get a feel for the visual story form used in the study. Use as much time as needed to review the example story. You will answer questions about the visual story on the next page. **Note:** The following example is a partial story, only presenting the beginning panels, and uses synthetic data. Subsequent visual stories are complete and use real datasets.

### Page #4: Training Questions

Please answer the following questions as they relate to the example visual story you just reviewed.

#### *Sample questions*

1. In your own words, please summarize the introduction to the visual story you just reviewed:  
 \_\_\_\_\_
2. Rate the degree to which you agree with the following statements (1=strongly disagree, 7=strongly agree): *randomize order*
  - The visual story excited me. (arousal +)
  - I enjoyed the visual story. (hedonic +)
3. What were the peak total online sales in the U.S. over the past 10 years? (Panel 2, accented; rank: attribute)
  - a. **380 billion**
  - b. 430 billion
  - c. 480 billion
  - d. Not sure
4. What year had the highest amount of online sales in the U.S.? (Panel 2, accented; rank:time)
  - a. 2006
  - b. 2011
  - c. **2016**
  - d. Not sure



## Visual Story A

### Page #5: Visual Story A

The following visual story discusses the topic of sea-level rise in the U.S. Please review the visual story using your **complete focus** (do not view other websites, split your attention, etc.).

### Page #6 Visual Story A Comprehension (*IV: Genre and Trope, RQ #1 and #2*) (*DV*)

Please answer the following written questions as they relate to the visual story on sea-level rise in the U.S. that you just reviewed. This survey relies on your written feedback, so please take time in preparing your responses.

1. In your own words, please summarize the visual story you just reviewed. Please be as comprehensive as possible? \_\_\_\_

### Page #7 Visual Story A Personal Reactions (*IV: Genre and Trope, RQ #1 and #2*) (*DV*)

1. Rate the degree to which you agree with the following statements about the visual story on sea-level rise in the U.S. (1=strongly disagree, 7=strongly agree): *randomize order*

- The visual story excited me. (arousal +)
- The visual story bored me. (arousal -)
- I enjoyed the visual story. (hedonic +)
- I was upset by visual story. (hedonic -)
- The visual story interested me. (interest +)
- The visual story concerned me. (interest -)
- I agree with the visual story. (belief +)
- The visual story did not influence my beliefs about sea-level rise. (belief -)

### Page #8 Visual Story A Retention (*IV: Genre and Trope, RQ #1 and #2*) (*DV*)

Please answer the following directed questions about specific aspects of the about the visual story on sea-level rise in the U.S.. Please complete the directed questions using your **complete focus** (do not view other websites, split your attention, etc.). You can mark only one answer for each response.

#### *Identify (6 tasks)*

What was the peak average temperature for the U.S. over the past 40 years? (Panel 2, accented; identify: attribute)

- a. 44.3 °F
- b. 54.3 °F

- c. 64.3 °F
- d. Not sure

What was the average coastal population density for New York in 2012? (Panel 3, accented; identify: attribute)

- a. **3,081 people per square mile**
- b. 3,581 people per square mile
- c. 4,081 people per square mile
- d. Not sure

What was the largest amount of sea level rise exhibited in a single year from 2002-2012? (Panel 4, accented; identify: attribute)

- a. **8.4 millimeters**
- b. 10.4 millimeters
- c. 12.4 millimeters
- d. Not sure

What was the average value of vulnerable coastal properties in North Carolina in 2012? (Panel 5, accented; identify: attribute)

- a. \$3,730
- b. \$5,730
- c. **\$7,730**
- d. Not sure

What was the largest rate of sea-level rise at a single New York station in 2012? (Panel 6, accented; identify: attribute)

- a. 2.4 millimeters/year
- b. **4.4 millimeters/year**
- c. 6.4 millimeters/year
- d. Not sure

According to the 2020 prediction, what will be the average per person value of vulnerable coastal properties in North Carolina? (Panel 9, accented; identify: attribute)

- a. \$125
- b. \$225
- c. **\$325**
- d. Not sure

***Compare (3 tasks)***

Which state had the larger coastal population density in 2012? (Panel 3, accented; compare: space)

- a. **New York**
- b. North Carolina
- c. They were about the same
- d. Not sure

Which state had the higher average value of vulnerable coastal properties in 2012? (Panel 5, accented compare: space)

- a. **New York**
- b. North Carolina
- c. They were about the same
- d. Not sure

According to the 2020 prediction, which state will have the larger per person value of vulnerable coastal properties? (Panel 9, accented compare: space)

- a. New York
- b. **North Carolina**
- c. The same
- d. Not sure

### ***Rank (3 tasks)***

Which year had the highest average temperature in the U.S. (Panel 2, accented; rank:time)

- a. 2005
- b. 2010
- c. **2015**
- d. Not sure

Which year from 2002 to 2012 exhibited the highest annual rise in sea levels? (Panel 4, accented; rank: time)

- a. 2004
- b. 2008
- c. **2012**
- d. Not sure

Which New York station had the highest rate of sea-level rise in 2012? (Panel 6, accented; rank: space)

- a. **Bergen Point**
- b. Montauk
- c. Port Jefferson
- d. Not sure

### ***Subjective***

Which state do you think is handling sea-level rise better?

- New York, and I would have guessed New York before reviewing the visual story.
- New York, but I would have guessed North Carolina before reviewing the visual story.
- North Carolina, and I would have guessed North Carolina before reviewing the visual story.
- North Carolina, but I would have guessed New York before reviewing the visual story.

- Not sure

## Visual Story B

### Page #9: Visual Story B

The following visual story discusses the topic of U.S. presidential campaign donations. Please review the visual story using your **complete focus** (do not view other websites, split your attention, etc.).

### Page #10 Visual Story B Comprehension (*IV: Genre and Trope, RQ #1 and #2*) (DV)

Please answer the following written questions as they relate to the visual story on U.S. presidential campaign donations that you just reviewed. This survey relies on your written feedback, so please take time in preparing your responses.

### Page #11 Visual Story A Personal Reactions (*IV: Genre and Trope, RQ #1 and #2*) (DV)

1. Rate the degree to which you agree with the following statements about the visual story on U.S. presidential campaign donations. (1=strongly disagree, 7=strongly agree): *randomize order*

- The visual story excited me. (arousal +)
- The visual story bored me. (arousal -)
- I enjoyed the visual story. (hedonic +)
- I was upset by visual story. (hedonic -)
- The visual story interested me. (interest +)
- The visual story concerned me. (interest -)
- I agree with the visual story. (belief +)
- The visual story did not influence my beliefs. (belief -)

### Page #12 Visual Story A Retention (*IV: Genre and Trope, RQ #1 and #2*) (DV)

Please answer the following directed questions about specific aspects of the about the visual story on U.S. presidential campaign donations. Please complete the directed questions using your **complete focus** (do not view other websites, split your attention, etc.). You can mark only one answer for each response.

#### *Identify (6)*

What was the peak U.S. presidential election campaign cost over the past 40 years? (Panel 2, accented; rank: attribute)

- \$1.34 billion
- \$1.54 billion
- \$1.74 billion**
- Not sure

What were Colorado's average campaign donations per person during the 2012 presidential election? (Panel 3, accented; rank: attribute)

- a. \$1.3 per person
- b. \$2.3 per person
- c. **\$3.3 per person**
- d. Not sure

What was the largest Democratic advantage in campaign donations in a single month during the 2012 presidential election? (Panel 4, accented; identify: attribute)

- a. \$41 million
- b. **\$51 million**
- c. \$61 million
- d. Not sure

What was the increase in the Democratic voting lead in Ohio from July to November during the 2012 presidential election? (Panel 5, accented; identify: attribute)

- a. **0.7%**
- b. 1.7%
- c. 2.7%
- d. Not sure

What was the largest Democrat's advantage in a single Colorado city in 2012 presidential election? (Panel 6, accented; identify: attribute)

- a. \$2,400,000
- b. \$3,400,000
- c. **\$4,400,000**
- d. Not sure

According to the 2020 prediction, what will be the voting change towards Republicans in Ohio from the 2016 presidential election ? (Panel 9, accented; identify: attribute)

- a. 2.5%
- b. 7.5%
- c. **12.5%**
- d. Not sure

### ***Compare (3)***

Which state had greater campaign donations per person during the 2012 presidential election? (Panel 3, accented; compare: space)

- a. **Colorado**
- b. Ohio
- c. They were about the same
- d. Not sure

In which state did the Democrats gain a larger voting lead from July to November during the 2012 presidential election? (Panel 5, accented; compare: space)

- a. **Colorado**
- b. Ohio
- c. They were about the same
- d. Not sure

According to the 2020 prediction, which state is expected to have the larger change in voting results from the 2016 presidential election? (Panel 9, accented; compare: space)

- a. Colorado
- b. **Ohio**
- c. They were about the same
- d. Not sure

### ***Rank (3)***

Which year had the highest cost for a U.S. presidential election? (Panel 2, accented; rank:time)

- a. 2004
- b. **2008**
- c. 2012
- d. Not sure

Which month exhibited the largest advantage in campaign donations for the Democratic party during the 2012 U.S. presidential election? (Panel 4, accented; rank: time)

- a. August
- b. **September**
- c. October
- d. Not sure

Which city in Colorado had the largest lead in the Democratic candidate's donations during 2012 presidential election? (Panel 6, accented; rank: space)

- a. Boulder
- b. **Denver**
- c. Grand Junction
- d. Not sure

### ***Subjective***

Which state do you think is handling presidential campaign donations better?

- Colorado, and I would have guessed Colorado before reviewing the visual story.
- Colorado, but I would have guessed Ohio before reviewing the visual story.
- Ohio, and I would have guessed Ohio before reviewing the visual story.
- Ohio, but I would have guessed Colorado before reviewing the visual story.
- Not sure

### Page #13: General Background Information (*Individual Differences, RQ #3*)

Thank you for reviewing the pair of visual stories! Before finishing the survey, please complete the following preference and background questions.

#### 1. *Story Preferences*

1. Rate the degree to which you agree with the following statements about the visual story form. (1=strongly disagree, 7=strongly agree):

- I *liked* vertically scrolling through all content. | I *liked* clicking through each panel in the slideshow.
- I instead would have *preferred* vertically scrolling through all content. | I instead would have *preferred* clicking through each panel in the slideshow.
- I instead would have *preferred* a video animation with narration.
- I instead would have *preferred* a single static map poster.
- I instead would have *preferred* a single interactive map.
- I instead would have *preferred* a printed, text-based write-up.
- I instead would have *preferred* a website with a text-based write-up.

2. Rate the degree to which you agree with the following statements about the visual story content. (1=strongly disagree, 7=strongly agree):

- I thought the story needed *more* text.
- I thought the story needed *less* text.
- I thought the story needed *more* numbers.
- I thought the story needed *less* numbers.
- I thought the story needed *more* maps.
- I thought the story needed *less* maps.
- I thought the story needed *more* graphics.
- I thought the story needed *less* graphics.
- I thought the story needed *more* interactivity.
- I thought the story needed *less* interactivity.

3. Rate the degree to which you agree with the following statements about the way content was highlighted in the visual story. (1=strongly disagree, 7=strongly agree):

- I *liked* the use of thick black outlines to emphasize important content.
- I *didn't notice* the use of thick black outlines to emphasize important content.
- I *liked* the use of annotations with connecting lines to emphasize important content.
- I *didn't notice* the use of annotations with connecting lines to emphasize important content

- I *liked* how the layout of text, maps, and graphics emphasized important content.
- I *didn't notice* how the layout of text, maps, and graphics emphasized important content.

## 2. Demographic

1. What is your gender identity? (*gender, IV*)
  - a. Male
  - b. Female
  - c. Other
2. What is your age? (*age, IV*) \_\_\_\_\_
3. Please specify your race/ ethnicity: (*race/ethnicity, IV*)
  - a. Asian
  - b. Black or African American
  - c. Hispanic or Latino
  - d. Native American or American Indian
  - e. Pacific Islander
  - f. White
  - g. Other: \_\_\_\_\_
4. Please specify your nationality: (*nationality, IV*)
  - a. USA
  - b. Other. List all: \_\_\_\_\_
  - c. USA and other: List others: \_\_\_\_\_
5. Is English your first language? (*language, IV*)
  - a. Yes
  - b. No
  - c. Other: \_\_\_\_\_
6. What state do you currently live in? (*geography: absolute, IV*) \_\_\_\_\_
7. Which of the following best describes where you live? (*geography: relative, IV*)
  - a. Urban
  - b. Suburban
  - c. Rural
  - d. Other: \_\_\_\_\_
8. What type of device are you using? (*tech, IV*)
  - a. Laptop
  - b. Desktop computer
  - c. Tablet
  - D. Other: \_\_\_\_.

## 2. Education & Motivation



1. What is the highest degree or level of **education** you have completed? (*expertise: educational attainment, IV*)

- a. Did not complete high school
- b. High school/GED
- c. Some college
- d. Undergraduate (Major(s) :\_\_)
- e. Master level (Subject: \_\_)
- f. Post-undergraduate certificate (Subject: \_\_)
- f. Advanced graduate work or PhD (Subject: \_\_)
- g. Other: \_\_. \_\_

2. On a scale of 1 to 7 (**1 is not familiar, 7 is very familiar**), please rate your level of **familiarity** with the following topics: (*expertise: familiarity, IV*)

- Print News Sources
- Online News Sources
- Maps
- Computing Technology
- The Internet
- Information Graphics
- Environment and Science
- Domestic Politics

3. On a scale of 1 to 7 (**1 is no training, 7 is lots of training**), please rate your level of **training** in the following topics: (*expertise: education, IV*)

- Print News Sources
- Online News Sources
- Maps
- Computing Technology
- The Internet
- Information Graphics
- Environment and Science
- Domestic Politics

4. Have you ever **worked** in any of the following areas? (*expertise: experience, IV*)

- Journalism. If yes, years\_\_ (for all)
- Mapping/Geospatial Industry
- Computing Technology or Information Technology
- Web Design
- Graphic Design
- Environment and Science
- Domestic Politics

5. On a scale of 1 to 7 (**1 is not interested, 7 is very interested**), please rate your level of **interest** in the following topics: (*motivation: interest*)

- Print News Sources
- Online News Sources

- Maps
- Computing Technology
- The Internet
- Information Graphics
- Environment and Science
- Domestic Politics

### 3. Ability

1. Do you have color blindness or color vision deficiency? (*color identification ability, IV*)
  - a. Yes. Please indicate what type of color blindness/ deficiency, if you know:\_\_\_\_.
  - b. No.
  - c. I don't know.
2. Do you have corrected vision? (*vision ability, IV*)
  - a. No
  - b. Yes, I currently wear glasses
  - c. Yes, I currently wear contacts
  - D. Yes, I currently wear both
  - d. Other. Please indicate:\_\_\_\_.

### 4. Personal belief/bias

1. Please use 1-2 sentences to describe your attitudes toward the following topics:
  - Sea-level rise:\_\_\_\_\_.
  - Presidential Election donations:\_\_\_\_\_.
2. I *identify* myself as: (1-7 Likerts):
  - Socially liberal-v-conservative
  - Fiscally liberal-v-conservative
  - Environmentally conscious-v-agnostic
  - Politically active-v-agnostic
3. How **concerned** are you about following topics? (Please circle the number corresponding to your level of concern, from 1-7)
  - Concern about sea-level rise
  - Concern about coastal vulnerability
  - Concern about presidential campaign donations
  - Concern about the presidential election results
4. On a scale of 1 to 7 (1 is strongly disagree, 7 is very agree), please rate your level of agreement of the following statements:
  - I think sea-level rise is a topic **worth discussing**.
  - I think presidential election donations are a topic **worth discussing**.
  - I **believe** sea-level rise is a problem.
  - I **believe** presidential election donations are a problem.

