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IN THIS ISSUE

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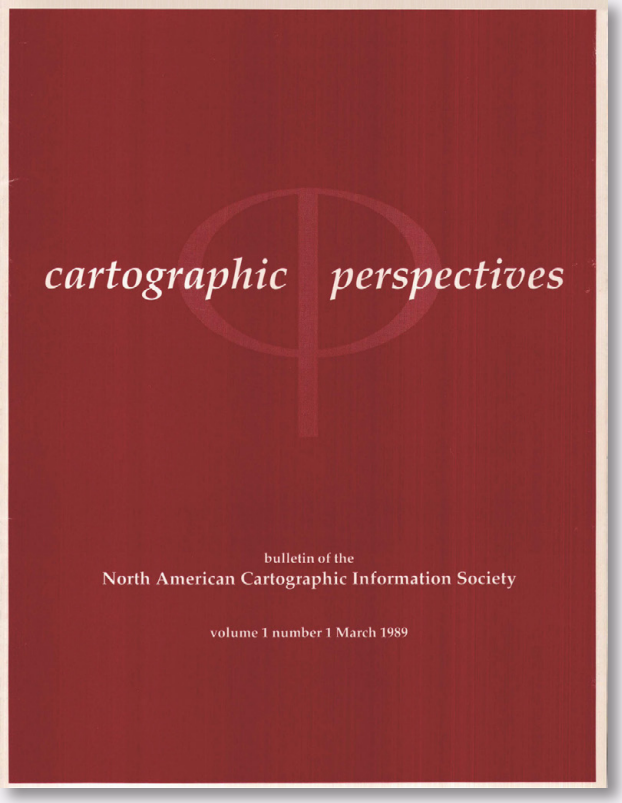
ABOUT THE COVER

For our hundredth issue, we feature an homage to the cover of the very first issue of *Cartographic Perspectives*, released in March of 1989. This design (with differing background colors) was followed through the first 13 issues, up until the fall of 1992. Head on over to cartographicperspectives.org to view our entire archive, and see how our journal has evolved over the decades. Here's to 100 more!



Cartographic Perspectives

The Journal of **nacis**

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All material published in the journal is independently reviewed and/or edited. Submissions are accepted from members of the journal staff and editorial board, but the authors play no role in the assessment or editing of their contribution.

LETTER FROM THE EDITOR

This issue marks an anniversary for *CP*, the hundredth issue of the journal. *CP 1* was published in 1989, and the inaugural co-editors were David DiBiase and Karl Proehl. Although I was not among its initial readers, with my first association with NACIS still a decade into the future, I can glean from those early issues that *CP* was established because the Society had outgrown its previous communications fora: two newsletters, called *Map Gap* and *Cartographic Information*. In the new journal, one aim was to publish original material rather than to (primarily) synthesize and collect reports of recent developments in the field. The new journal was also envisaged as a means for linking the multiple constituencies that had engaged with the organization as it grew and matured, a task that was harder before the internet connected us all.

Reading David's message to NACIS members from that first issue, my eye was caught by the following quote:

> My goal for CP is that it be a forum every member feels comfortable contributing to, and that each issue contain a variety of contributions from several members. All are encouraged to submit reviews, reports, abstracts of "fugitive cartographic literature," notices, open letters, comments or complaints. There is a place in this Bulletin for a range of prose forms, from the formal solicited article to the informal notice posted on the "Cart Lab Bulletin Board." Graphical submissions are also welcome.

Although *CP* no longer has a section called the CART LAB BULLETIN BOARD, in part because so few universities have been wise enough to retain their cartography labs (in my view missing a great opportunity for education and community engagement), *CP* does still have a range of sections where members working in different contexts and with different mapping-related interests can contribute. For those of us whose everyday work does not involve writing in public fora, contributing to *CP* may seem daunting. I can say that my section editor colleagues, our Assistant Editor, Daniel Huffman, and I have worked hard to support anyone who wants to contribute to the journal to develop that contribution, no matter their level of comfort or prior experience with writing for a journal.

Over its existence, *CP* has had nine Editors (Figure 1) each of whom has helped to build the journal in their own way, responding to the needs of the Society at the time, and to broader changes in cartography and in academic publishing. Under their leadership, *CP* has stood apart from other cartographic journals through its distinctive outlook and its

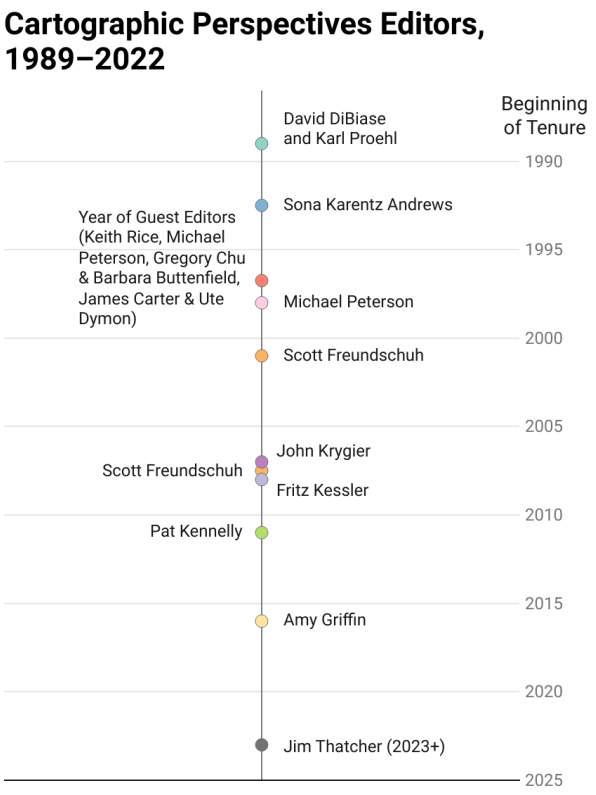


Figure 1. *Cartographic Perspectives* editors, 1989–2022 (*CP1–100*).

willingness to innovate in ways that have often been ahead of their time. For example, from 1999 onwards we offered authors the ability to publish figures in color, which was not commonplace at the time, much less made available—as we did—at no cost to the author. We were the first cartographic journal to become fully open access, a decision that was implemented in 2011 after consulting with the NACIS membership. *CP* is still the only cartographic journal that supports open-access publication with no fees for authors. Like the Society's decision to record and publish **presentations from the Annual Meeting** on YouTube, being an open-access journal is true to the spirit of the Society in that it seeks to enable the widest possible range of people to participate in our community. Cost, at least, is no barrier to reading the journal. Visually, too, *CP* has remained at the leading edge. Tanya Buckingham Andersen, who helped lead the transition to an open-access model, took the opportunity to update the look of *CP*. Our layout, which has since been further developed by Daniel Huffman, draws upon the design traditions of our profession to present a more accessible alternative to the bland, authoritative style (to use a category coined by Ian Muehlenhaus, one of our editorial board members) used by most scholarly journals.

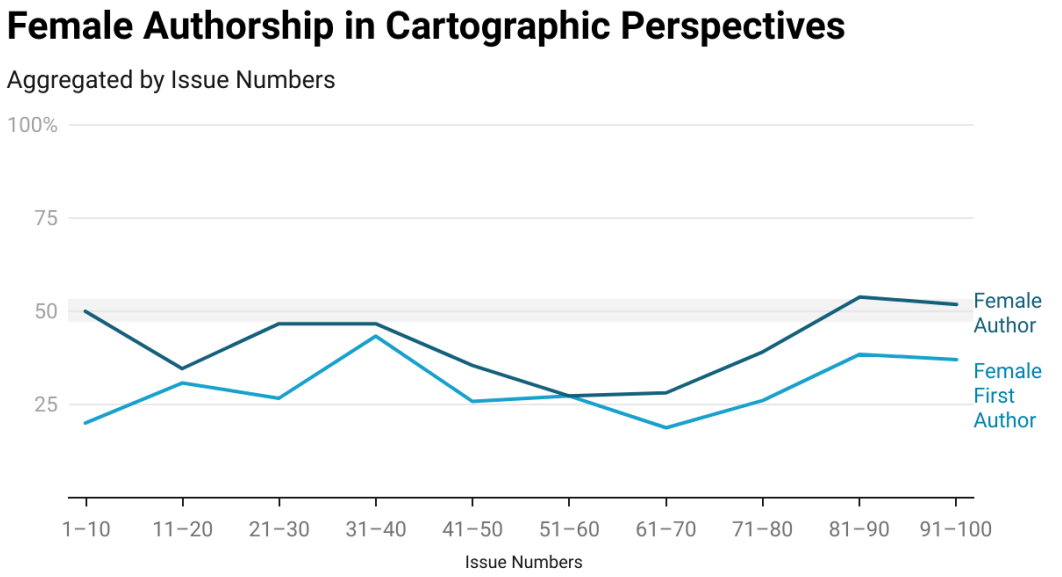
Our journal's distinctive approach aims to represent the full diversity of cartographic practice. Most scholarly journals publish only materials that are directed towards an audience of academics and researchers. From the very beginning, *CP* has had sections that speak to practicing cartographers, those working with cartographic collections, and those working on the artistic side of cartography. Because our book reviews are written not only by academics, they highlight where books have value for cartographers working in roles other than research, making our reviews section stronger and more useful to the wider membership than that of a typical journal.

There is more we can do to support participation by a diverse range of cartographers, and the journal's editorial board will listen to and consider any suggestions made by Society members that might widen participation in the journal's conversations. As I thought about how I might try to understand the trajectory of the journal over time, I sat down to look at all of the "featured articles" from *CP* 1 onwards.[1] Inspired by the society's discussions about

1. "Featured articles" are those that have undergone a peer-review process with several experts in the specific topic that the article addresses. Early in *CP*'s history, these articles were directly commissioned by the editors, but as the journal grew, it began to review and accept unsolicited contributions from authors.

diversity and inclusion over the past several years, I decided to focus on trying to understand how *CP* has or has not been representative of different voices in the field. Limiting myself to only this subset of articles necessarily offers a constrained view of the journal, but as the section for which I have been most responsible, it is the section I know the best. Moreover, as the section with the greatest number of "gatekeepers"—the peer reviewers as well as the editor—there may be a greater number of barriers to participation by a diverse set of authors in the "featured articles" section than in the other sections. Although there are many dimensions we could examine as far as whose voices are being heard (e.g., gender, race/ethnicity, age, employment sector), few of them can be understood without the systematic collection of demographic data, which *CP* has not done for its authors. However, unlike some personal characteristics like race/ethnicity or age, we can attempt to infer gender identities from author names with a reasonable level of accuracy. This admittedly forces a binary classification of a non-binary aspect of a person's identity. Although this is not optimal, in the absence of historical self-identification information, this is the only available information to understand gender differences in participation. Where possible, inferred gender identity was cross-referenced with pronouns the author used on a webpage or other publication.

Figure 2 shows the participation rate by females in the "featured articles" category of submissions published in *CP*, across the journal's history. The authorship data are aggregated into ten-issue units to smooth the spikiness of the trends that result from small numbers of articles when considering single issues. The chart also shows the percentage of papers that had female first authors, who are assumed to have made the most substantial contribution to the work described in the article. Female participation has ranged from 27% to 54%, with three groups of issues exceeding the 50% threshold, and an overall participation rate of 40%. Females are less likely to have been first authors on the papers I examined than to have participated in some other way. Female first authorship rates have ranged from 19% to 43%, with an overall rate of 29%. There does not appear to be a strong upward or downward



Because the journal has not historically asked authors to self-identify their gender, gender has been inferred from names. This forces a binary classification of a non-binary aspect of a person's identity. Although this is not optimal, in the absence of self-identification information, this is the only available data to understand gender differences in participation.

Figure 2. Female authorship in *Cartographic Perspectives*, issues 1–100.

trend in either overall participation or first authorship rates, and the analysis would benefit from contextual data on female participation in the broader field of cartography over the time period. Nevertheless, having basic knowledge of participation levels is a prerequisite to identifying and understanding participation barriers, and this analysis presents a very modest first step in that direction.

Throughout its existence, *CP* has published on a wide range of topics of cartographic interest, ranging from humanities-influenced research on the role of maps in literature and art, the contributions to the history of cartography, or philosophies of mapping; all the way to science- and engineering-influenced research that develops new algorithms or mapping production technologies. Somewhere in the middle of these two poles, of course, is design-focused research wherein a new design is developed and sometimes evaluated with map users.

While some topics have been of persistent interest, others have changed through the journal's history as practices of mapmaking and the membership of the Society have themselves changed. An examination of the fifty words most frequently found in the abstracts of published papers (again aggregated into ten-issue units) reveals, unsurprisingly, that **map(s)**, **mapping**, **cartographic**, **cartography**, **data** (or its counterpart **information**), and **design** always make an appearance. **Atlas(es)** have also often been a perennial point of discussion, moving up and down the frequency rankings, with a major pulse appearing due to issue 20, which was a special issue focused on atlas design. Other words appear only over shorter time periods. For example, abstracts of early issues often mentioned **production**, **paper**, **computer**, **software**, **animation**, **retrieval**, and **electronic**, perhaps because production technologies were still undergoing major changes at that point. **Internet** and **web** make their first appearances in the data for issues 21–30 and 31–40, respectively, and then return again as **online** in more recent issues (81–90 and 91–100). Later issues show more concern with how we are designing maps to be used and how people are using them, with words such as **interaction**, **use**, **experience**, and **evaluation** frequently mentioned in recent journal issues. Finally, we can see the influence of special issues that focus on particular themes, through the appearance of words that appear in only one or two of the aggregate units, such as **art**, **aesthetics**, **terrain**, **ski**, and **emotional**. Somewhat surprising is the fact that words related to coding, now used to produce many maps, do not make an appearance in the most frequent word lists of any period. This may, however, have looked quite different if all sections of the journal had been examined instead of just the featured articles.

I encourage you all to explore the *CP* archives. There are some fascinating pieces that appear in the journal's history, and the author list reads like something of a who's who in cartography, with many prominent scholars having published at least once in the journal (e.g., Waldo Tobler, Alan MacEachren, Mark Monmonier, Michael Goodchild, Ferjan Ormeling, Cynthia Brewer, Barbara Buttenfield, Rob Roth, and Anthony Robinson). Our most frequent contributors, with twelve and eleven articles, respectively, have been the NACIS stalwarts Adele Haft, who brought to our attention the role of maps in poetry and who for many years was a fixture at the Annual Meeting, and Tom Patterson, who has generously shared his knowledge of mapping terrain with the NACIS community for several decades. In this issue of *CP*, you can find some new work on terrain mapping that has clearly benefitted from these past publications.

On that note, in *CP 100*, you will find three PEER-REVIEWED ARTICLES. In the first, Zihan Song and colleagues examine the relative success of two different genres of storytelling with maps (the longform infographic and the dynamic slideshow) and two different ways of focusing the reader's attention on important aspects of the story (color highlighting and leader lines). Their study found that leader lines and the longform infographic format presented some advantages in making the story memorable and understandable. In the second article, Nathaniel Douglass and Carolyn Fish explore combinations of thematic terrain layers (hypsometric tints, land cover, and orthoimagery) with shaded relief produced by different methods (hand-drawn relief, multidirectional hillshade, and ray-traced relief shading). Their study examined how different combinations of these two layer types affected how map readers assessed the map's beauty, level of realism, and the clarity of its different landforms. In the final article, Nolan Mestres breaks down the stylistic elements of Pierre Novat's hand-painted winter panorama maps. Mestres highlights key elements that make Novat's maps distinctive in comparison with those produced by other painters such as Heinrich Berann or James Niehues (whose maps also feature in this issue of *CP)*. Novat's maps, which can be found all over France in its many ski resorts, helped to shape how people in France saw mountain regions at a time when there was significant expansion of ski resorts.

In CARTOGRAPHIC COLLECTIONS, Charles Preppernau interviews James Niehues, a contemporary painter who is well known for his panorama maps of ski resort areas in the United States, among other places. This beautifully illustrated interview discusses some of the challenges of creating clear yet recognizable views of terrain, and various ways that Niehues experimented with different solutions to develop his mapping style. It also introduces Niehues's most recent project, the *Great American Landscape Project*.

CP100 includes three REVIEWS. Rosemary Wardley reviews the latest atlas produced by the 2017–2018 **Corlis Benefideo Award**-winning team of **James Cheshire and Oliver Umberti**, *The Atlas of the Invisible*. In it, the authors aimed to reveal invisible influences on how we live in today's world, by drawing on both new data sources and existing data sources that they visualized in new ways. In addition to enlightening us about these invisible influences, Wardley recommends the book as a design inspiration source book. R. C. Ramsey next reviews *Women and GIS: Mapping their Stories,* in which the Esri Press authorial team quite directly aims to make women working in the GIS and mapping disciplines more visible by profiling women with successful careers in the industry and sharing their stories of how they built a successful career. Of particular value, Ramsey notes, is the book's discussion of how these women not only embarked on, but *sustained* their careers. Finally, Nat Case reviews *Frederick Law Olmsted: Plans and Views of Communities and Private Estates*. This reference volume, part of a larger, multi-volume collection, focuses on Olmsted's private commissions. A key point of its value, according to Case, is the way that site photos and plans are juxtaposed to better allow the reader to see how Olmsted's vision might be brought to life within the landscape.

After this issue is published, I will be handing over the reins to the 10th editor, Jim Thatcher, who will bring fresh ideas about where to take the journal in its next phase of development. I will leave it to Jim to communicate what his ideas for the journal are, but from what I do know of his plans, I am sure his editorial philosophy will honor journal's founding aims, and I look forward to seeing future issues that will undoubtedly include thought-provoking pieces.

Before signing off, I'd like to offer my thanks to the very large number of people who have worked with me to help produce the journal over my tenure as editor. This support, just like most of what makes NACIS tick, is almost all volunteered; for that, I am very grateful. It has been especially appreciated the last few years as I navigated some particularly challenging professional and personal circumstances in addition to the of ever-shifting COVID-land weirdness we have all travelled through. Some of these individuals have served in multiple roles and are named only once here for brevity. They include Daniel Huffman (Assistant Editor), Margot Carpenter (Cartographic Collections section editor), Nick Bauch (Visual Fields section editor), Fritz Kessler (Views on Cartographic Education section editor), Mark Denil (Reviews editor), Susan Peschel (NACIS Business Manager), previous section editors (Sarah Bell, Jake Coolidge, Matt Dooley, Terri Robar, Angie Cope, Alex Tait, Laura McCormick, Lisa Sutton), current and past editorial board members (Sarah Battersby, Raechel Bianchetti, Cynthia Brewer, Matthew Edney, Sara Fabrikant, Bernhard Jenny, Pat Kennelly, Mark Monmonier, Ian Muehlenhaus, Michael Peterson, Anthony Robinson, Amy Rock, and Robert Roth), the dozens of experts who have provided reviews of manuscripts, contributors who sent their good work to the journal, and finally, you, the readers, without whom there would be no point in producing a journal.

I encourage you to dip into this landmark issue of *CP* and consider how you can contribute to its cartographic conversations.

Amy Griffin (she/her)
Editor, *Cartographic Perspectives*

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PEER-REVIEWED ARTICLE

Visual Storytelling with Maps: An Empirical Study on Story Map Themes and Narrative Elements, Visual Storytelling Genres and Tropes, and Individual Audience Differences

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Visual storytelling describes the communication of stories through illustrations, graphics, imagery, and video instead of, or in addition to, oral, written, and audio formats. Compared to their popularity and wide reach, empirical research on map-based visual stories remains limited. We work towards infilling this gap through an empirical study on data journalism, providing the first assessment of four emerging design considerations for visual storytelling with maps: story map themes and their constituent narrative elements, visual storytelling genres, visual storytelling tropes, and individual audience differences. Specifically, we recruited 125 participants to an online map study, requiring them to separately review two visual stories and respond to a series of free-response and Likert scale questions regarding their retention, comprehension, and reaction. We followed a 2×2×2 factorial design for the visual stories, varying their themes (US presidential campaign donations, US coastal sea-level rise), *genres* (longform infographic, dynamic slideshow), *and tropes* (color highlighting, leader lines), *while holding other design dimensions constant. The story theme did not influence the participants' total retention or comprehension, indicating that a three-act narrative and its constituent elements can be applied consistently and effectively across variable kinds of topics. Instead, genres and, to a weaker degree, tropes influenced total participant retention, pointing to the importance of intentional design in map-based visual storytelling. Overall, participants performed better when the visual storytelling designs used* longform infographics *or "scrollytelling" (genres) to structure content and* leader lines *(tropes) to visually accent information. In contrast, the story theme influenced audience reaction, with participants feeling significantly more concerned about and upset with the* US presidential campaign donations *story compared to the* US sea-level rise *story. Individual audience differences by expertise, motivation, and prior beliefs also influenced participant reaction. Our study signals a need for establishing a research and education agenda on map-based visual storytelling in both cartography and data journalism.*

KEYWORDS: visual storytelling; data journalism; spatial narratives; story maps; scrollytelling; narrative visualization

INTRODUCTION

Here, we report on empirical research aimed at understanding how to design maps that support visual storytelling. Mapping and storytelling have long been intertwined (Denil 2017). The fourth-century *Classic of Mountains and Seas* made visual the mythical story of ancient China; the medieval Beatine Map was embedded within and reinforced the story of Christianity; Ogilby's *Britannia* atlas of 1675 presented sequenced recollections of life on the road in an increasingly interconnected Britain. While any storyteller can use maps, graphics, sketches, etc., to advance

their narrative and enhance their story, spatialized stories designed by cartographers traditionally were contained within the margins of a single printed map or unfolded through an atlas-like sequence of bound maps (Ormeling 1995). In the following, we use *story* to describe an account of specific events, places, and people, and *narrative* to describe the structure and presentation of this content that shapes the meaning of the story (Pearce 2008).

Arguably, both maps and stories are more accessible and influential today than ever due to pervasive computing, innovations in new media, and advancing geoweb technologies (Haklay, Singleton, and Parker 2008; Sui and Goodchild 2011; Sieber et al. 2016; Young, Hermida, and Fulda 2018). Unsurprisingly, narrative and storytelling have garnered substantial research attention at the intersection of cartography, geography, and GIScience (e.g., Elwood 2006; Pearce 2009; Phillips 2012; Caquard 2013) and increasingly are topics of inquiry in related, visual-centric fields such as information visualization and visual analytics (e.g., Gershon and Page 2001; Eccles et al. 2008; Ma et al. 2012; Kosara and Mackinlay 2013). Professionally, the use of maps and graphics for storytelling has become a defining trait of *data journalism*, or news stories supplemented and even generated by analysis and presentation of digital information (Gray, Chambers, and Bounegru 2012). While journalists have a long history of using data-driven maps as evidence in their news reports (Monmonier 1989), many news organizations are exploring novel narrative structures and design strategies as they transition from a primarily print to a primarily digital medium (Wallace 2016; Cairo 2017). In the following, we adopt a broad definition of *visual storytelling* as the communication of stories through illustrations, graphics, imagery, and video instead of or in addition to oral, written, and audio formats (for a review of storytelling visualizations, see Segel and Heer 2010).

Despite both scholarly and practical advancement in the history, application, and critique of narrative and story in cartography and related fields, there remains relatively limited empirical research on the intentional *design* of visual stories, particularly on map-based strategies and techniques, and the subsequent interpretation of these designs by their audiences. We addressed this gap through an empirical study providing the first assessment of four emerging design considerations for visual storytelling with maps: story map themes and their constituent narrative elements, visual storytelling genres, visual storytelling tropes, and individual audience differences. Specifically, we asked:

1. ***What is the influence of story map themes and their constituent narrative elements on the audience's retention, comprehension, and reaction?*** Visual stories covering different kinds of topics, or story *themes*, still can share design similarities based on the underlying narrative structure. A *three-act narrative*—dating to Aristotle's *Poetics* (ca. 335 BCE) and commonly adopted in play- and screenwriting—comprises a set-up (Act 1), a conflict/confrontation (Act 2), and a resolution (Act 3) to give the story a beginning, middle, and ending. Each act includes recurring *narrative elements* paced to build suspense through rising action and then tie up loose threads through falling action. The elements of a three-act narrative can inform the selected sequence of maps and graphics for a visual story, enforcing continuity to produce a linear reading of inherently non-linear, often two-dimensional, geographic information. For our research, we designed two map-based visual stories on timely topics seen in US media outlets, using a consistent three-act narrative structure and similar constituent narrative elements: the first about the influence of *US presidential campaign donations* on election results and a second about the influence of *US coastal sea-level rise* on climate change vulnerability.

2. ***What is the influence of visual storytelling genres on the audience's retention, comprehension, and reaction?*** Broadly, a *genre* is a category of literature, music, or other form of artistic expression that exhibits similarity in structural and stylistic elements (see Cartwright [1999] for the first reference to genres related to storytelling in cartography). Our prior work has extended Segel and Heer (2010) to identify seven visual storytelling genres made possible by developments in pervasive computing, new media, and geoweb technologies (Roth 2021). These genres differ by the visual or interactive techniques they use to enforce continuity of elements in the narrative sequence. In the research we present here, we examined differences in the audience's retention, comprehension, and reaction between two visual storytelling genres: *longform infographic*s and *dynamic slideshows*.

3. ***What is the influence of visual storytelling tropes on the audience's retention, comprehension, and reaction?*** A *trope* is a literary or rhetorical device used to advance a story, much like a figure of speech (Smith 1996). We previously established seven visual storytelling tropes that capture a range of design techniques used not to represent information, but to advance the narrative and develop narrative elements (Roth 2021). Employing visual storytelling genres that enforce a linear, three-act narrative utilizes a first trope—continuity—by unifying otherwise disparate visual elements into a logical structure (Gershon and Page 2001). In addition, we examined design techniques used to focus attention—a second trope first discussed by Gershon and Page—on important or unusual information that should not be missed by the audience. Specifically, we investigated differences in the audience's retention, comprehension, and reaction between two visual attention strategies commonly used in cartography and information visualization (e.g., Robinson 2011; Griffin and Robinson 2015): *leader lines* and *color highlighting*.

4. ***What is the influence of individual audience differences on their retention, comprehension, and reaction?*** Visual stories are presented from a situated perspective and invite the audience to draw from their personal backgrounds and experiences to derive meaning from the story (Pearce 2014). Maps and stories are persuasive and political (Harley 1989; Cronon 1992), and commonly are employed together for controversial, divisive topics (Vujaković 2014; Kent 2017). Multiple personal characteristics can influence retention, comprehension, and reaction, and therefore the success of a visual story design. We term these variable audience characteristics *individual differences*, and collected information on expertise, motivation, and prior beliefs on a number of topics related to visual storytelling to examine the influence of individual audience differences on retention, comprehension, and reaction.

We addressed these research questions through an online map study with 125 participants recruited from Amazon Mechanical Turk. The study required participants to separately review two visual stories and then respond to a series of multiple choice, free response, and Likert scale questions to assess their retention, comprehension, and reaction. We followed a 2×2×2 factorial design for our visual story materials, varying one of our test dimensions (themes, genres, or tropes) while holding the others constant, resulting in eight unique visual story designs in total. The remainder of this paper describes related background work, specifics about our method design, overall results, and concluding take-homes for the intentional design of map-based visual stories.

RELATED WORK

"Spatial narratives," "story maps," and "visual storytelling" are now commonplace terms in the cartographic lexicon, often evoked to simultaneously describe a mode of individual expression, a visual design method, and a technological platform. Research on "narrative cartography" is as diverse as that on maps themselves, with storytelling opening new intellectual spaces for cinematic (e.g., Caquard and Taylor 2009; Muehlenhaus 2014), imaginative (e.g., Joliveau 2009; Caquard 2011), Indigenous (e.g., Chapin, Lamb, and Threlkeld 2005; Pearce and Louis 2008), literary (e.g., Moretti 2005; Bushell 2012), multimedia (e.g., Monmonier 1992; Cartwright 1999), and participatory (e.g., Elwood 2006; Miller 2006) mappings. Maps can give spatial structure to oral, written, and audio-visual forms of storytelling (Caquard and Cartwright 2014), and often are combined with graphics, images, videos, and text to provide a deep account of people, places, and events (Macfarlane 2007).

We explored map-based visual storytelling through the lens of data journalism, an area that has seen increased research and professional interest in cartography, information visualization, and related fields (for recent edited volumes, see Gray, Chambers, and Bounegru 2012; Riche et al. 2018; Engebretsen and Kennedy 2020). 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 within the data (Weber and Rall 2012; Rogers 2014). Thus, the data journalism process is much like the highly iterative process we follow in cartography: both journalist and cartographer are active in shaping an

explanation of the compiled text, graphics, and images. In other words, both maps and news stories—and the various combinations therein—exhibit purposeful *design* (Roth 2021). In our research, we approached four emerging design considerations for visual storytelling using a case study in data journalism.

STORY MAP THEMES AND THREE-ACT NARRATIVE ELEMENTS

First, we drew from elements of a linear, three-act narrative to inform the content and sequence of maps, graphics, and text for two different visual storytelling themes common in data journalism. Conceptually, nearly all data journalism lends itself to mapping, as events occur in specific geographic, historical, and social contexts. Vujaković (2014, 15) characterizes seven "news maps" *themes* and 18 sub-themes receptive to mapping in data journalism, ranging from environmental concerns to politics. Each story theme covers a unique knowledge domain and therefore may represent a different reporting responsibility in a news room, with the themes broad enough to apply to many geographic locations.

If the theme informs the content of the story, a linear narrative provides design guidance for structuring and presenting this story content. In this way, map-based visual stories covering very different themes can share similarities in their design if using the same narrative structure (see Phillips 2012 for an analysis of common narrative structures in geography), and consideration of the constituent *narrative elements* of this structure during story planning offers new opportunities for visual story design. Specifically, we organized narrative elements into a *three-act* structure defining the beginning, middle, and end of each of our story themes:

1. The *set-up* (Act 1) introduces the *setting*, *key characters*, and *problem context*. The set-up often includes a *hook*, or an exciting early scene that captures the attention of the audience and encourages them to continue reading. For visual storytelling, a map primarily frames the setting and problem context in the set-up act, but places depicted within the map also can be treated as exemplar *protagonist* or *antagonist* characters.

2. The *conflict* or *confrontation* (Act 2) first intervenes with the *problem*, or key issue driving the story, and then slowly builds suspense through rising *plot points*. The problem produces *tension* among characters, particularly between the protagonist and antagonist for critical juxtaposition. The characters respond and evolve at each plot point. In a cartographic context, individual plot points can be represented as either unique symbols and annotations within a single map or unique maps within a broader sequence of graphics, images, and text. Accordingly, representation of a single narrative element often is described as a *frame* within the overall visual story (after Pearce 2008).

3. The *resolution* (Act 3) culminates the narrative arc with the dramatic *climax*, or final confrontation between characters. The resolution concludes the story with falling action in the *denouement*, in which remaining matters are explained or resolved. Several narrative elements can be left unresolved for the audience in a *cliffhanger*, stimulating their imagination and curiosity while allowing them to "fill in the gaps" using their own experiences and predictions.

There are a number of modifications and extensions of a three-act narrative (see Hullman et al. 2013; Thöny et al. 2018), and visual storytelling often deviates from a linear narrative to temporarily withhold information or build suspense (Muehlenhaus 2014). However, we tested two different visual story themes instead of two different narrative structures, both to simplify the factorial study design described below and to mitigate the effect of participant biases towards any single theme, which otherwise might skew our results when testing other visual story design considerations (i.e., genres and tropes). We selected the case studies of *US presidential campaign donations* and *US coastal sea-level rise* to exemplify Vujaković's (2014) "Politics, Internal" versus "Environment and Science" themes, two timely topics in US media outlets. **Table 1** defines the aforementioned constituent elements of a linear, three-act narrative based on Roth (2021) and describes their application to the two case studies used in the online study.

VISUAL STORYTELLING GENRES

Second, we examined the influence of the visual storytelling genre on participants' retention, comprehension, and reaction. Segel and Heer (2010, 1139) proposed seven basic "genres of narrative visualization," differentiating

Narrative Element	Description	Story 1: US Presidential Campaign Donations	Story 2: US Sea-level Rise Vulnerability
Theme	The general thematic category of the visual story (Vujakovic 2014)	A. Politics: internal; 1. Government	D. Environment and Science; 8. Environmental problems/ impacts
Topic	The specific geographic phenomenon or process covered in the visual story	US presidential campaign donations	US sea-level rise
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
Summary	A brief introduction to the visual story following a three-act narrative structure	***Purpose:*** *This story follows two swing states—Colorado and Ohio—to explain the impact of campaign donations on the US presidential election results.* ***Problem:*** *Differences in party campaign donations influenced voting results in many swing states during the 2012 Presidential Election.* ***Resolution:*** *Colorado and Ohio represent different alternatives for addressing campaign donations.*	***Purpose:*** *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 the US.* ***Problem:*** *Rising sea levels have increased the vulnerability of properties on the East Coast of US since 2012.* ***Resolution:*** *New York and North Carolina represent different alternatives for addressing sea-level rise.*
Act 1: Set-up			
Setting	The specific place, time, and social context, giving the story a geography		
Space	Where the story takes place	US Swing States	US Eastern Coastal States
Time	When the story occurred	The 2012 US Presidential Election	The 2012 Hurricane Season
Characters	The people or places who embody the narrative and act-out the plot		
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
Antagonist (accented)	The character in opposition to the protagonist	Ohio: A swing state whose voting support was largely not influenced by an advantage in campaign donations by either party	North Carolina: A coastal state whose vulnerability was largely not influenced by rising sea levels
The Hook (Panel 1)	An exciting early scene 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
Problem Context (Panel 2)	Additional background information needed to interpret the story later in the narrative sequence	**Title**: What Is Happening with Our Elections? It Starts with Rising Campaign Costs. **Fact:** US presidential campaign costs have increased nearly 800% in the past 40 years. **Accent:** Campaign costs peaked at $1.74 billion in the 2008 presidential election. **Graph:** *Y value:* Presidential Election Costs ($ Billion); *X value:* Year.	**Title:** What is Happening with Our Coasts? It Starts with Rising Temperatures. **Fact:** US average temperatures have increased almost 3 °F in the past 40 years. **Accent:** US average temperatures peaked at 54.3 °F in 2015. **Graph:** *Y value:* Average Temperature (°F); *X value:* Year.
Problem Context (Panel 3)	Additional background information needed to interpret the story later in the narrative sequence	**Title:** Why Do Costs Matter? More than 50% of Campaign Funds were from Donations in 2012. **Colorado:** The average person in Colorado donated $3.30 during the 2012 presidential election. **Ohio:** The average person in Ohio donated only $1.50 during the 2012 presidential election. **Legend:** *title:* Presidential Campaign Donations; *description:* Average donations per person ($), 2012 presidential election.	**Title:** Why Do Coasts Matter? More than 50% of US Citizens Lived in Coastal Areas by 2012. **New York**: 3,081 people live in an average square mile of New York coasts. **North Carolina**: Only 73 people live in an average square mile of North Carolina coasts. **Legend:** *title:* Coastal Population Density; *description:* Average people per square mile of coastal area, 2012.

Table 1. Elements of a Three-act Narrative. A linear, three-act narrative comprises a set-up (Act 1), conflict/confrontation (Act 2), and resolution (Act 3). This table describes how we applied the constituent elements of a linear, three-act narrative to the pair of visual stories used in this study. Continued on the next page.

Act 2: Conflict/Confrontation			
Problem/ Catalyst (Panel 4)	The central confrontation, obstacle, or setback driving the story	**Title:** So What? Increasing Donations Pose A Problem… **Fact:** The Democrat advantage in campaign donations reached $253 million for the 2012 presidential election. **Accent:** Democrats received $51 million more donations than Republicans in September, the largest donations advantage during the 2012 president election. **Graph:** *Y value:* Cumulative Donation Gap ($ Million); *X value:* Month	**Title:** So What? Rising Sea Levels Pose a Problem… **Fact**: The US average sea levels in 2012 reached 47.8 millimeters above the 2002 average. **Accent:** Global sea levels rose 8.4 millimeters in 2012, the largest sea-level rise from 2002-2012. **Graph:** *Y value:* Cumulative Sea Level Change (Millimeters); *X value:* Year.
Tension (Panel 5)	The impact of the problem on the protagonist versus the antagonist	**Title:** …Particularly for Swing States. **Colorado:** Democrats increased their support by 6.5% in the swing state of Colorado. **Ohio**: Democrats only increased their support by 0.7% in the swing state of Ohio. **Legend:** *title:* Increase in Voting Lead; *description:* Change in Democratic lead (% total), July 2012 poll to Nov 2012 election.	**Title:** …Particularly for States on the East Coast. **New York:** The average value of vulnerable properties in coastal areas is $24,800 in New York. **North Carolina**: The average value of vulnerable properties in coastal areas is only $7,730 in North Carolina. **Legend:** *title:* Property Vulnerability; *description:* Average value of vulnerable coastal properties ($), 2012
Plot Points (Panel 6)	One in a sequence of events motivated by the problem that impacts the characters (Cause)	**Title:** A Deeper Look: Democrats Gained their Largest Donation Advantage in Major Cities. **Fact:** Democrats drew 140% more urban-based donations per person in Colorado than Ohio, largely attributed to the progressive Denver metro area. **Accent:** The Democrats gained an advantage of $4,400,000 in Denver, the highest urban lead in swing states; **Legend:** *title:* Donation Gap *description:* Democrat advantage in campaign donations ($), 2012	**Title:** A Deeper Look: Sea Levels Rose the Most in Major Stations. **Fact:** 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. **Accent:** Sea-level annual rate in Bergen Point is 4.4 millimeters, the highest rate among stations in coastal states. **Legend:** *title:* Average Sea-Level Rise *description:* Average annual sea-level rise (millimeters/ year), 1992–2012.
Act 3: Resolution			
Climax (Panel 7)	The final plot point bringing characters together to face their tension and consider competing solutions (Effect)	**Title:** As a Result, Campaign Donations Have a Different Influence on Election Results in Swing States like Colorado versus Ohio. **Colorado:** Every $100 advantage for the Democrats bought 7.5 votes in Colorado. **Ohio:** Every $100 advantage for the Democrats bought only 2.8 votes in Ohio.	**Title:** As a Result, Sea-level Rise Has a Different Impact on Vulnerability in Coastal States like New York versus North Carolina. **New York:** Every inch in sea-level rise exposes $3,900 of property in New York. **North Carolina**: Every inch in sea-level rise only exposes $1,400 of property in North Carolina.
Resolution & Denoue-ment (Panel 8)	Falling action in which all remaining matters with the setting, characters, and problem context are explained or resolved	**Title:** What's Next? Colorado and Ohio Represent Different Alternatives for Addressing Campaign Donations. **Colorado:** Colorado has imposed new regulations to limit campaign funding since the 2012 presidential election. **Ohio:** At the same time, Ohio has failed to act on campaign funding.	**Title:** What's Next? New York and North Carolina Represent Different Alternatives for Addressing Sea-level Rise. **New York:** New York has invested considerable public funds to prevent sea-level rise related crises. **North Carolina:** At the same time, North Carolina has failed to act on sea-level rise.
Cliffhanger (Panel 9)	The dramatic ending, leaving open strands for the audience to ponder	**Title:** What Do You Think We Should Do As a Nation? **Colorado:** 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. **Ohio:** 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. **Legend:** *title:* Voting Results Predictions, 2020 Presidential Election; *description:* Predicted Republican voting lead; Predicted Democratic voting lead	**Title:** What Do You Think We Should Do as a Nation? **New York:** The value of vulnerable properties per person in New York is predicted to increase to $290 by 2020 if sea levels continue to increase at a consistent rate. **North Carolina**: The value of vulnerable properties per person in North Carolina is predicted to increase a surprising $325 by 2020 if sea levels continue to increase at a consistent rate. **Legend:** *title:* Predicted Property Vulnerability; *description:* Increased value of vulnerable coastal properties per person ($), 2020 Prediction

Table 1 (continued). Elements of a Three-act Narrative. A linear, three-act narrative comprises a set-up (Act 1), conflict/confrontation (Act 2), and resolution (Act 3). This table describes how we applied the constituent elements of a linear, three-act narrative to the pair of visual stories used in this study.

each genre by the number and order of frames within the story: magazine style, annotated chart, partitioned poster, flow chart, comic strip, slide show, and film/video/animation. While foundational, the original Segel and Heer taxonomy drew primarily upon printed news maps and passive television news reporting, thus preceding many emerging design practices made possible by pervasive computing, new media, and geoweb technologies (Kosara and Mackinlay 2013). Further, the number of frames is less relevant with these emerging technologies, where page space is unlimited. In response, we previously proposed a revised taxonomy of visual storytelling *genres* based only on the visual or interactive technique used to enforce continuity of elements in the narrative sequence:

Genre	Linearity Definition
Static Visual Story	Linearity is enforced through partitioning of the layout into frames and clarifying annotation.
Longform Infographic	Linearity is enforced through vertical reading and browser scrolling.
Dynamic Slideshow	Linearity is enforced by advancement through a series of slides.
Narrated Animation	Linearity is enforced by the progression of digital display time.
Multimedia Visual Experience	Linearity is enforced by anchor tags and hyperlinking.
Personalized Story Map	Linearity is enforced by the order that an individual contributes content to the map.
Visual Story Compilation	Linearity is enforced by unfolding events in near real-time or major updates to the design.

Table 2. Visual Storytelling Genres. Visual storytelling genres are defined by the visual or interactive technique used to enforce linearity of elements in the narrative sequence. This table describes the taxonomy of visual storytelling genres introduced by Roth (2021), expanded from Segel and Heer (2010). We examined the longform infographic and dynamic slideshow genres in this study.

static visual stories (encapsulating most of the Segel and Heer taxonomy), longform infographics, dynamic slideshows (from Segel and Heer), narrated animations (from Segel and Heer), multimedia visual experiences, personalized story maps, and compilations (Roth 2021; **Table 2**). We also imagine the ability to mash up these genres, combining different visual or interactive techniques for enforcing continuity within a single visual story.

Of these possible genres, we narrowed our focus for this research to longform infographics and dynamic slideshows. *Longform infographics* enforce continuity through vertical reading and browser scrolling, with the genre often described as "scrollytelling" by data journalists (Stolper et al. 2016, 8; citing Bostock 2014). In contrast, *dynamic slideshows* enforce continuity by advancement through a series of visual panels or frames of consistent size and format, producing a discrete, typically horizontal scroll versus the continuous vertical scroll of longform infographics; this discrete sequencing of content sometimes is described as "pagination" when used as a web design strategy (Wieczorek et al. 2014, 310). We selected these two genres for our initial investigation in order to contrast the slideshow presentations common across academia, government, and industry (Kosara and Mackinlay 2013) with the longform infographic or "scrollytelling" approaches now common in news media, as this structural difference in the method for enforcing continuity between the two genres (and across all genres) potentially influences the audiences' retention, comprehension, and reaction. For instance, eye-tracking studies have shown that scrollable web content promotes visual skimming (Nielsen 2006), a potential disadvantage of longform infographics compared to dynamic slideshows. In contrast, dynamic slideshows explicitly dose information into less complex slides to reduce skimming, an advantage previously found to aid retention in text presentations (Wieczorek et al. 2014). However, the scrolling in longform infographics enables continuous, audience-driven pacing (Harrower and Sheesley 2005), and thus makes the user more active in the experience. In contrast, dynamic slideshows require discrete advancement of slides at a potentially monotonous pace that is designer-driven, which may be exacerbated by lags from reloading wrapper page content for each slide. We provide additional discussion on the relative advantages and limitations of different visual storytelling genres in Roth (2021).

VISUAL STORYTELLING TROPES

Third, we considered new visual design techniques—described as *tropes*—used not to represent information, but rather to enhance the narrative. Our use of tropes synthesized disparate literature on narrative cartography and visualization. For instance, Gershon and Page (2001, 34) described "story-like visual presentation," listing storytelling concepts like conflict and ambiguity resolution, continuity, effective redundancy, filling gaps, increasing

attention, and setting the mood. Similarly, Pearce (2009, 4) combined "narrative techniques" like ambiguity, closure, focalization, scale, and voice to express "qualities of place: intimacy, identity, and connection with the reader." Elsewhere, such tropes are described collectively as storytelling affordances (Kosara and Mackinlay 2013), devices (Segel and Heer 2010), or figures (Cattoor and Perkins 2014). As described in our prior work, we organized these existing concepts and recommendations into seven design tropes for visual storytelling: continuity (central to the delineation of the different genres described above), mood, dosing, attention, redundancy, metaphor, and voice (Roth 2021; **Table 3**). Each trope then has an associated set of design techniques that can be employed for visual storytelling.

Trope	Definition
Continuity	Unify otherwise disparate visual elements into a logical structure.
Mood	Set a visual tone congruent with the narrative and its elements.
Dosing	Reduce overall complexity of story content into incremental chunks of information.
Attention	Emphasize important or unusual information that cannot be missed in the story.
Redundancy	Repeat important or unusual information to develop story themes.
Metaphor	Bring together seemingly unrelated concepts in a single frame to facilitate understanding of complex narrative elements.
Voice	Embed situated experiences, opinions, and values into the visual story to clarify meaning.

Table 3. Visual Storytelling Tropes. Visual storytelling tropes are design techniques used not to represent information, but rather to enhance the narrative. This table summarizes emerging tropes identified by Roth (2021). Two visual accenting solutions for focusing attention were examined in this study: color highlighting and leader lines, following Griffin and Robinson (2015).

In addition to differences in continuity by genre, we examined different methods for focusing attention on important or unusual information in the story that should not be missed (Gershon and Page 2001). *Attention* as a trope describes a range of design solutions that produce an "Isolation Effect," making one item stand out over others in a visual scene (Lidwell, Holden, and Butler 2010, 254). Commonly used techniques for focusing attention in cartography and visualization include highlighting features through the visual variables (e.g., Robinson 2011); applying annotations such as leader lines, flow arrows, appended geometric frames, opacity masks, numbering, call-outs, and labels (e.g., Pearce 2008); and creating dynamic changes through blinking/flickering, panning/zooming, and focus+context visualizations (e.g., Weber Reuschel, Piatti, and Hurni 2014). We provided additional discussion of these focusing attention techniques in Roth (2021) using the catch-all term *visual accenting*. In the presented study, we specifically examined the differences in attention between *leader lines* and *color highlighting* within a single representation, similar to Griffin and Robinson's (2015) investigation into the use of these two visual accenting techniques for focusing attention between two coordinated representations. Notably, Griffin and Robinson found leader lines to perform equally well as the more common color highlighting for focusing attention between coordinated views. We held all other visual storytelling tropes constant across tested materials.

INDIVIDUAL DIFFERENCES

Finally, we addressed the role of individual differences among the audience on the effectiveness of visual storytelling. Just like maps, stories and their meanings are not fixed or objective truths, but rather are shaped by the situated backgrounds and experiences of both storyteller and audience (after Haraway 1991; Rose 1997). While our contribution in this paper is to the design of map-based visual stories, and new ways that a cartographer or data journalist can shape the narrative, we recognize that the same design will conjure different understandings and evoke different responses from different people in different places (Pearce 2014). An advantage to taking a narrative approach to cartography is that it enables the embrace of pluralism—a data feminism principle—allowing designers to be more transparent in their positionality

toward the story theme, while also inviting the audience to form multiple, equally-valid story meanings (adapted from D'Ignazio and Klein 2020). Considering the individual audience differences that influence visual storytelling can help cartographers and data journalists make more informed choices about their designs (Fish 2020b).

To this end, we drew upon work on mapping context and individual differences in cartography and visualization (see Griffin et al. 2017 for a comprehensive review and synthesis). Expanding upon our prior work (Roth 2009), we first collected several measures of our participants' expertise—including their education, training, familiarity, and interest—regarding topics related to map-based visual storytelling. These included their experience with different news media (print and online), maps and information graphics, computing technology and the internet, and relevant news story themes.

We then collected measures of *motivation* regarding the same topics, an individual difference we have found to be as important as expertise for the success of web maps (Roth and Harrower 2008).

Finally, we assessed *prior beliefs* developed from past experience with topics related to the visual stories that may bias a reader in favor for or against a contentious position. Regarding map-based visual stories, prior beliefs may persist even in the face of evidence that invalidates them (Cohen 2012). Both tested themes followed Phillip's (2012) cause and effect three-act narrative structure, and we embedded a subtle conservative lean in the *US presidential campaign donations* visual story and a subtle liberal lean in the *US coastal sea-level rise* visual story to balance prior beliefs for the other visual story design considerations. We did not assess the influence of other sociodemographic differences, given the sensitivity of the visual story themes and the focused goals of the research.

METHODS

PARTICIPANTS

One hundred twenty-five participants completed an online map study assessing their retention, comprehension, and reaction across different map-based visual story designs. We recruited participants from Amazon Mechanical Turk in March 2017—after first conducting a pilot survey with four participants in a controlled environment in the University of Wisconsin Cartography Lab to capture potential issues with the survey design. The pilot study resulted in small text and styling changes, but no major changes to the study design.

Recruitment using Mechanical Turk has both advantages and limitations for our study (see Hauser, Paolacci, and Chandler 2019 for expanded discussion). We chose Mechanical Turk over alternatives, such as university student recruitment pools, to capture greater demographic, geographic, and political diversity among participants, which was important for our ability to assess the influence of individual differences and, specifically, prior beliefs, on participants' retention, comprehension, and reaction. However, recruitment with Mechanical Turk restricted us from purposefully sampling by individual differences without the risk of dramatically oversampling one group; accordingly the sample variability in individual differences may have an influence on the study results. Additional limitations include variable participant attention and experience with research studies, which we mitigated partially through questions on individual differences and balanced experimental procedure. Finally, Mechanical Turk has prompted new ethical considerations for human subjects research regarding the exploitation of labor and associated expected quality of experimental results (D'Ignazio and Klein 2020). We designed the survey to take 30 minutes to complete, and participants received $4 USD for compensation, a rate that exceeded the Wisconsin minimum wage at the time of the study ($7.25/hr USD). Participants completed the survey with a median time of 30.71 and average of 34.64 minutes.

Of the 125 participants in our sample, 71 identified as male and 54 as female, with zero responses to non-binary categories, and an average age of 35 years old. Nineteen participants did not attend college, 43 attended some college or were attending college, 55 completed an undergraduate degree, six completed a graduate degree, and two reported "Other."

Online participants completed the survey on their own computing devices and were instructed to use non-mobile devices. Sixty-three participants completed the survey on a laptop computer and 62 on a desktop computer. Because

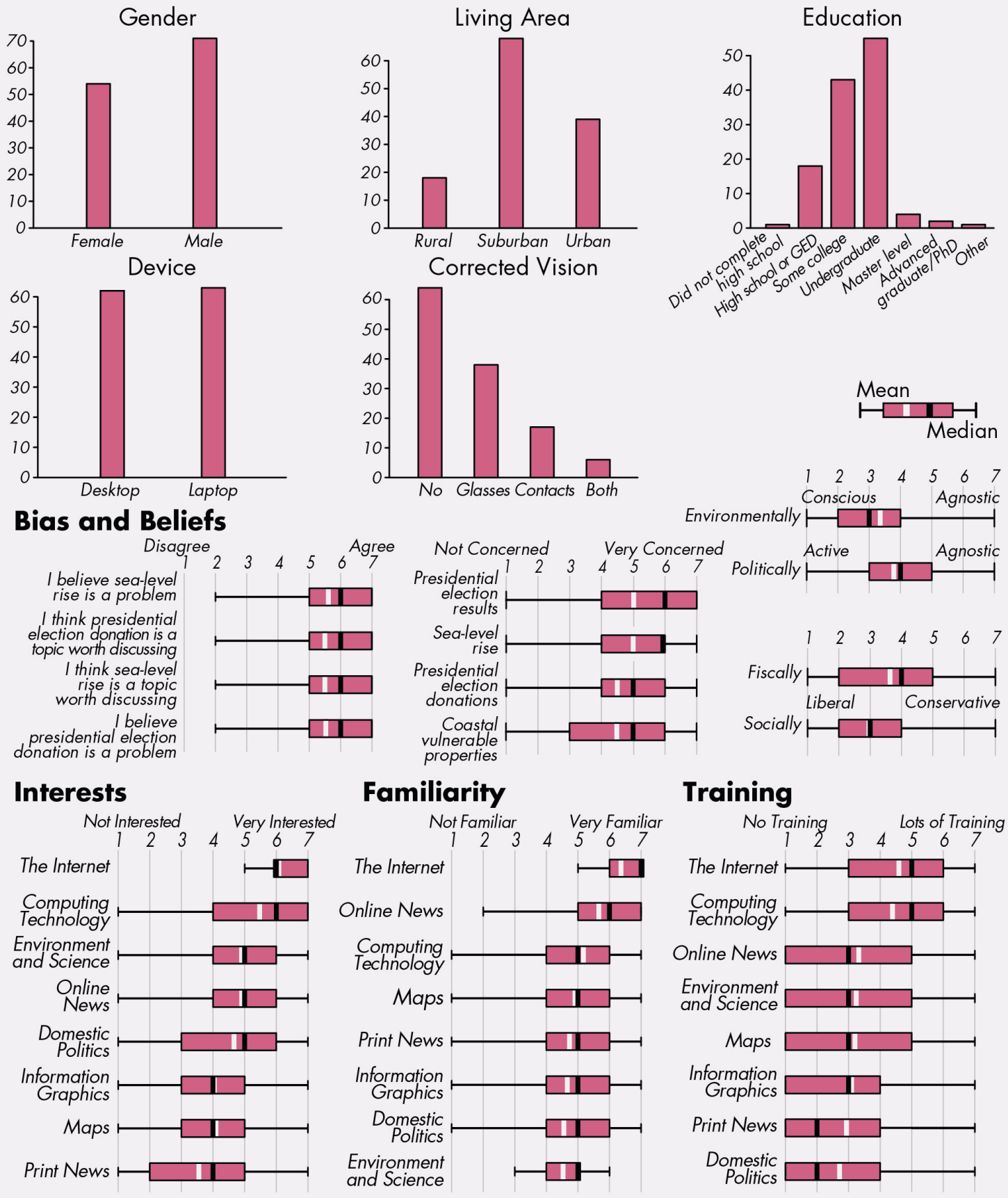

Figure 1. Participant characteristics.

all evaluated map-based visual stories dealt with US-based issues (see below), we limited participation to the US general public. **Figure 1** provides an overview of participant characteristics; the **Supplemental Materials** include an additional breakdown of the sample by individual differences by experimental condition.

MATERIALS

The online map study followed a 2×2×2 factorial design (Montello and Sutton 2012):

- Factor 1: *Themes*. Conditions consisted of stories on *US presidential campaign donations* and *US sea-level rise*, exemplifying Vujaković's (2014) "Politics, Internal" and "Environment and Science" themes. Both conditions followed Phillip's (2012) cause and effect three-act narrative structure and used real data for their contents, with *US presidential campaign donations* receiving a subtle conservative lean in the cause and effect structure and *US sea-level rise* a subtle liberal lean to balance effects from prior beliefs.

- Factor 2: *Genres*. Conditions consisted of *longform infographics* and *dynamic slideshows*. We first dosed story content for both conditions into nine-frame storyboards (three frames per act)—with each frame representing a different narrative element—and then assembled the frames using the continuity technique defining the given genre (continuous scrolling versus discrete slide advancement, respectively) to promote information equivalency between conditions. We loaded all nine frames onto the survey webpage for the *longform infographics* condition, although frames were spaced so that only one was visible at a time while scrolling up to a 1080p resolution screen in order to mimic "lazy loading" of content that was conventional in web design at the time of the study. In contrast, only one frame was loaded into the webpage at a time for the *dynamic slideshow* condition, again following convention at the time of the study of AJAX (Asynchronous JavaScript and XML) or separate webpages to load content on demand. The result was an intentional delineation in the experience between continuous and discrete scrolling. Participants could return to prior frames in both genres (i.e., scroll-up, previous slide), but were prevented from returning to the visual stories after advancing past the last frame.

- Factor 3: *Tropes*. Conditions consisted of two common design solutions for focusing attention, *leader lines* and *color highlighting*. We used black for *color highlighting*, as black was not used for symbolization and therefore could be applied consistently across the graphics. The use of black also avoided any potential issues with color vision deficiency in the participant sample. For design consistency, leader lines also used black strokes. The attention solutions were applied to the protagonist and antagonist in each design, leading to the introduction of two complementary place-based characters for each story.

The 2×2×2 factorial design resulted in construction of eight unique stories (**Table 4**). The overall aesthetic style

Story	Theme (Factor 1)	Genre (Factor 2)	Trope (Factor 3)
Story 1	US sea-level rise	Longform Infographic	Color highlighting
Story 2	US presidential campaign donations	Longform Infographic	Leader lines
Story 3	US presidential campaign donations	Longform Infographic	Color highlighting
Story 4	US sea-level rise	Longform Infographic	Leader lines
Story 5	US presidential campaign donations	Dynamic Slideshow	Leader lines
Story 6	US sea-level rise	Dynamic Slideshow	Color highlighting
Story 7	US sea-level rise	Dynamic Slideshow	Leader lines
Story 8	US presidential campaign donations	Dynamic Slideshow	Color highlighting

Table 4. Factorial Design. The study followed a 2×2×2 factorial design, resulting in eight unique visual stories.

and layout (i.e., mood), the amount and complexity of story content (i.e., dosing), and the visualization designs remained consistent for comparability. **Figure 2** provides an overview of the two, nine-frame visual stories and **Figure 3** provides a preview of the survey interface for advancing both genres. All tested materials are included in the **Supplemental Materials**.

PROCEDURE

The online map study began with an overview of project purpose and goals. After obtaining consent, participants completed a training block to combat learning effects. The training block contained the opening three frames of a third example visual story on US bookstore sales that followed the same design rules of other materials and included similar questions as the other experimental blocks (also included in **Supplemental Materials**). Participants were allotted as much time as needed to review the training block before progressing to the experimental blocks.

Participants then completed two experimental blocks covering the *US presidential campaign donations* and *US sea-level rise* themes (**Table 5**). We assigned Factors 1 (themes) and 3 (tropes) within-subjects, with assignment balanced so that

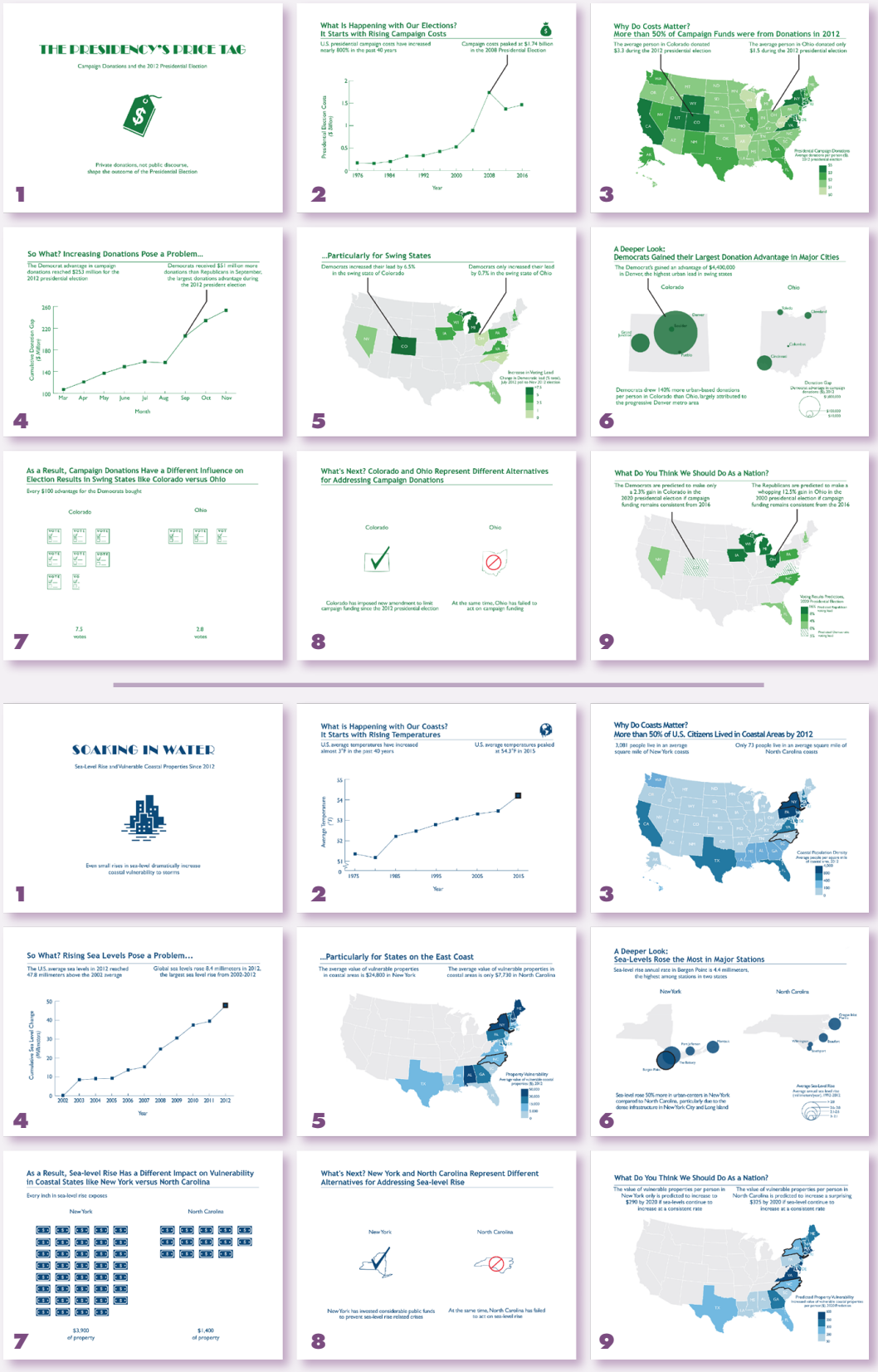

Figure 2. Visual Story Design. Both visual story themes were designed as a nine-panel sequence—with each panel representing a different narrative element (Table 1)—that could be presented as either a longform infographic or dynamic slideshow. **Top:** The *US presidential campaign donations* theme using *leader lines*. **Bottom:** The *US sea level rise* theme using *color highlighting*. High resolution versions of all tested materials are available as supplemental materials.

each possible combination of themes and tropes was viewed by approximately one quarter of the study participants. We assigned Factor 2 (genres) between-subjects so that participants viewed just one linear structure during the survey, limiting confusion over layout and interface changes to the survey instrument between the two blocks.

Participants responded to questions on separate survey pages after reviewing the visual story in full. Common measures of map design effectiveness include accuracy/correctness, response time, and completeness (Sweeney, Maguire, and 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. Finally, we have advocated in prior work to evaluate visual stories as much on their "effectiveness" as on how they make the audience feel about the depicted geographies (Roth 2021). Accordingly, participants responded to three kinds of questions about the story within each block, with each set of questions its own survey page:

1. *Retention*: The retention page included 12 multiple choice questions built from benchmark mapping tasks (Roth 2013). We included these questions to supply baseline "accuracy" or "correctness" metrics common in empirical research on map design outside of visual storytelling (after Sweeney, Maguire, and Shackel 1993). The questions varied on the level of predicted difficulty: three ordinal compare tasks (easiest), three ordinal rank tasks, and six numerical identify tasks (hardest). All tasks were phrased at an elementary map reading level to focus attention onto specific narrative elements in the visual story (Andrienko, Andrienko, and Gatalsky 2003). The twelve questions were randomized to avoid learning effects between blocks. We placed the retention questions at the end of the experimental block to reduce short-term recall, with retention questions following the comprehension and reaction questions.

2. *Comprehension*: Participants summarized the content of the story through a single, open-ended question, which we added to capture qualitative

Figure 3. Survey Design. The survey design used two different interactive techniques to advance frames based on the examined genre. **Top:** The *longform infographic* condition loaded all frames into the webpage and used browser scrolling by mouse wheel or side scroll bar to advance frames, spaced to show only one frame at a time. **Bottom:** The *dynamic slideshow* condition loaded one frame at a time and used bottom "Back" and "Next" buttons to advance frames.

Group	Sample Size (n=125 total)	First Viewed	Second Viewed
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 5. Group Assignment. Each participant reviewed both visual story themes, with the visual stories presented in the same genre but using different trope solutions.

and potentially meaningful engagement and interest with the visual story (after Kosara and Mackinlay 2013; Figueiras 2014). We instructed participants to be as comprehensive as possible and to use their own words when phrasing their summary. We then coded the open-ended responses following tenets of qualitative data analysis (Caudle 2004), with codes based on the narrative elements shaping the visual stories: setting (space, time), characters (protagonist, antagonist), problem, cause, effect/resolution, and cliffhanger, as well as a final code to capture any mistakes in comprehension (e.g., see Table 1 for example statements that would be coded as "comprehended"). Thus, the coding scheme measured whether purposeful treatment of these narrative elements in the visual story design resulted in reader comprehension. The codes were binary based on presence or absence within the participant open-ended response (i.e., did the participant comprehend the narrative element correctly in their response). The first 10% of the comprehension responses were coded by two, independent coders to hone code definitions and clarify ambiguity in the coding scheme.

3. *Reaction*: Participants responded to a series of seven-point Likert scales to capture how they felt about the visual stories and their depicted places and people (after Roth 2021). Reaction scales included participant interests in and beliefs about the visual story. Participants also self-reported their core affect in reaction to the visual story, including audience arousal (activated vs. deactivated) and hedonic valence (pleasant vs. unpleasant; Griffin and McQuoid 2012).

Participants completed this set of questions for both experimental blocks, resulting in responses to 250 unique blocks through the sample of 125 participants.

Participants concluded the study with an exit survey to characterize individual differences that might influence retention, comprehension, and reaction. The exit survey included questions on expertise, motivation, and prior beliefs using ordinal Likert scales. The complete online map study protocol is available in the **Supplemental Materials**.

ANALYSIS

Each factor (*themes*, *genres*, *tropes*) in the study design served as an independent variable, with responses to retention, comprehension, and reaction serving as dependent variables, respectively, and individual differences as interaction effects. We applied factorial ANOVA to assess the influence of the three factors on retention, comprehension, and reaction, as well as the pairwise interaction effects between factors to establish independence. We used factorial ANOVA instead of individual *t*-tests to mitigate alpha accumulation (Type I error) across a large number of hypothesis tests. We prepared a separate factorial ANOVA model for each unique retention (**Table 6**), comprehension (**Table 7**), and reaction (**Table 8**) measure, resulting in 23 total factorial ANOVA models. **Figures 4**, **5**, and **6** visually illustrate differences by conditions for the retention, comprehension, and reaction measures, respectively, marking differences by themes, genres, or tropes identified as significant through factorial ANOVA.

We then used multiple linear regression (MLR) models to assess the influence of individual differences on retention and comprehension (**Table 9**). We used MLR over a series of Spearman rank correlations again to mitigate alpha accumulation. MLR quantifies the relationship of predictors to a single response variable in the form of *B weight* coefficients (Nathans, Oswald, and Nimon 2012). We chose the B weight, which is unstandardized, to assess variable importance because each predictor variable was measured in the same units (Allen 2017). A coefficient of zero indicates the predictor has no influence on the response variable while a positive/negative coefficient indicates that, with all other variables held constant, for every increase of one unit in the predictor, the response variable increases/decreases on average the value by of the coefficient respectively. Since some questions capturing individual differences were specific to one story over the other, we ran three different MLR models for comprehension and retention: responses to the *US presidential campaign donations* condition alone, the *US sea-level rise* condition alone, and pooled responses together for individual differences relevant to both conditions.

We used a version of ordinal linear regression (OLR) known as the proportional odds model (POM) to analyze the reaction Likert scales (Brant 1990; **Table 10**). POM is a non-parametric method that quantifies the proportional odds ratio (θ) between predictor variables and the response

variable (McCullagh 1980). The range of the odds ratio is from 0 to positive infinity, with every one-point increase in the Likert scale predictor having x times (odds ratio) the odds of the response variable being a unit higher. For instance, a one unit increase in a predictor with an odds ratio of 1.4 increases the odds of the response variable being one unit higher by 40%. We ran eight models testing the influence of individual differences on each of the eight reaction Likert scales.

We also tested for multicollinearity among measures of individual differences to reduce the variance/standard error in the regression coefficient estimates. We calculated the variance influence factors (VIFs) for all individual differences and removed variables with VIFs over 4 to reduce multicollinearity, as VIF=4 means that the standard error for the coefficient of that predictor variable is 2 times (i.e., the square root of 4) larger than if that predictor variable had 0 correlation with the other predictor variables (Lavery et al. 2019). We removed seven of the collected individual difference measures as a result, which are highlighted in yellow in the results tables.

In the following discussion, we present retention results first, as comprehension and reaction enrich the quantitative analysis on retention. We present interaction effects from individual differences last.

Factor / Interactions		Compare (Ordinal)			Rank (Ordinal)			Identify (Numerical)			Total Retention		
Descriptive Statistics	n		Mean	SD		Mean	SD		Mean	SD		Mean	sd
Total	3000		81.9%	24.5%		71.7%	27.4%		66.2%	26.8%		71.4%	20.7%
US presidential campaign donations	1500		84.3%	27.0%		63.5%	27.6%		65.3%	27.2%		69.6%	21.6%
US sea-level rise	1500		79.5%	21.5%		80.0%	24.7%		67.1%	26.5%		73.3%	19.6%
Longform infographics	1512		84.9%	21.3%		70.9%	27.6%		71.0%	24.4%		74.5%	18.2%
Dynamic slideshows	1488		78.8%	27.0%		72.6%	27.2%		61.3%	28.3%		68.3%	22.6%
Leader lines	1500		84.0%	24.5%		73.3%	27.4%		69.2%	26.8%		73.8%	20.7%
Color highlighting	1500		79.7%	25.4%		70.1%	27.4%		63.2%	27.1%		69.1%	20.9%
Factorial ANOVA	df	Mean Sq	F	p	Mean Sq	F	p	Mean Sq	F	p	Mean Sq	F	p
Theme	1	1.30	2.44	0.12	15.38	25.12	0.00	0.68	0.27	0.60	12.10	2.03	0.16
Genre	1	2.13	4.01	0.05	0.16	0.26	0.61	21.35	8.52	0.00	33.75	5.67	0.02
Trope	1	0.97	1.83	0.18	0.73	1.19	0.28	8.22	3.28	0.07	20.93	3.51	0.06
Theme : Genre	1	0.05	0.09	0.76	0.77	1.25	0.26	1.30	0.52	0.47	0.13	0.02	0.88
Theme : Trope	1	0.21	0.40	0.53	2.46	4.01	0.05	3.74	1.49	0.22	14.72	2.47	0.12
Genre : Trope	1	0.18	0.33	0.57	0.02	0.03	0.85	0.63	0.25	0.62	0.13	0.02	0.88
Residuals	243	0.53			0.61			2.51			5.96		

Table 6. Participant Retention Results. The table shows descriptive statistics (top) and factorial ANOVA (bottom) for retention. The table includes main effects by factor (theme, genre, and trope) as well as interaction effects between factors. The table includes four separate factorial ANOVA models on retention for compare (ordinal), rank (ordinal), identify (numerical), and total retention. Color indicates significance: $p < 0.10$, $p < 0.05$, $p < 0.01$, $p < 0.001$.

Factor / Interactions		Space			Time			Protagonist			Antagonist			Problem		
Descriptive	n		mean	sd		mean	sd		mean	sd		mean	sd		mean	sd
Total	250		26.5%	44.2%		18.0%	38.5%		59.6%	49.2%		52.4%	50.0%		96.0%	19.6%
US presidential campaign donations	125		35.2%	48.0%		24.0%	42.9%		52.0%	50.2%		48.8%	50.2%		96.0%	19.7%
US sea-level rise	125		17.7%	38.4%		12.0%	32.6%		67.2%	47.1%		56.0%	49.8%		96.0%	19.7%
Longform infographics	126		32.5%	47.0%		18.3%	38.8%		60.3%	49.1%		50.8%	50.2%		99.2%	8.9%
Dynamic slideshows	124		20.3%	40.4%		17.7%	38.4%		58.9%	49.4%		54.0%	50.0%		92.7%	26.0%
Leader lines	125		24.0%	42.9%		19.2%	39.5%		60.8%	49.0%		52.0%	50.2%		95.2%	21.5%
Color highlighting	125		29.0%	45.6%		16.8%	37.5%		58.4%	49.5%		52.8%	50.1%		96.8%	17.7%
Factorial ANOVA	df	Mean Sq	F	p	Mean Sq	F	p	Mean Sq	F	p	Mean Sq	F	p	Mean Sq	F	p
Theme	1	1.94	10.49	0.00	0.90	6.23	0.01	1.44	6.02	0.01	0.32	1.27	0.26	0.00	0.00	1.00
Genre	1	0.96	5.19	0.02	0.00	0.01	0.92	0.01	0.06	0.82	0.07	0.26	0.61	0.26	6.82	0.01
Trope	1	0.17	0.92	0.34	0.03	0.19	0.66	0.05	0.20	0.66	0.00	0.01	0.92	0.02	0.42	0.52
Theme : Genre	1	0.58	3.13	0.08	0.47	3.24	0.07	0.20	0.83	0.36	0.00	0.02	0.89	0.02	0.40	0.53
Theme : Trope	1	0.06	0.34	0.56	0.26	1.82	0.18	0.05	0.19	0.66	0.00	0.00	1.00	0.00	0.00	0.99
Genre : Trope	1	0.00	0.00	0.98	0.13	0.88	0.35	0.18	0.76	0.38	0.01	0.02	0.88	0.00	0.00	0.98
Residuals	243	0.18			0.14			0.24			0.26			0.04		

Factor / Interactions		Tension			Cause			Effect			Cliffhanger			Total			Mistakes		
Descriptive	n		mean	sd		mean	sd		mean	sd		mean	sd		mean	sd		mean	sd
Total	250		69.2%	46.3%		32.4%	46.9%		50.8%	50.1%		26.8%	44.4%		48.0%	22.9%		12.4%	33.0%
US Presidential campaign donations	125		71.2%	45.5%		20.8%	40.8%		44.0%	49.8%		25.6%	43.8%		46.4%	22.7%		16.0%	36.8%
US sea-level rise	125		67.2%	47.1%		44.0%	49.8%		57.6%	49.6%		28.0%	45.1%		49.6%	23.0%		8.8%	28.4%
Longform infographics	126		69.8%	46.1%		35.7%	48.1%		50.8%	50.2%		27.0%	44.6%		49.4%	21.7%		11.1%	31.6%
Dynamic slideshows	124		68.5%	46.6%		29.0%	45.6%		50.8%	50.2%		26.6%	44.4%		46.6%	24.0%		13.7%	34.5%
Leader lines	125		73.6%	44.3%		35.2%	48.0%		50.4%	50.2%		25.6%	43.8%		48.4%	23.2%		13.6%	34.4%
Color highlighting	125		64.8%	48.0%		29.6%	45.8%		51.2%	50.2%		28.0%	45.1%		47.6%	22.6%		11.2%	31.6%
Factorial ANOVA	df	Mean Sq	F	p	Mean Sq	F	p	Mean Sq	F	p	Mean Sq	F	p	Mean Sq	F	p	Mean Sq	F	p
Theme	1	0.10	0.46	0.50	3.36	16.36	0.00	1.16	4.63	0.03	0.04	0.18	0.67	5.18	1.21	0.27	0.32	2.98	0.09
Genre	1	0.01	0.05	0.83	0.28	1.36	0.25	0.00	0.00	1.00	0.00	0.00	0.95	3.93	0.92	0.34	0.04	0.39	0.53
Trope	1	0.47	2.19	0.14	0.24	1.15	0.28	0.00	0.01	0.94	0.03	0.17	0.68	0.47	0.11	0.74	0.03	0.29	0.59
Theme:Genre	1	0.11	0.52	0.47	0.32	1.56	0.21	0.11	0.43	0.51	0.10	0.48	0.49	0.25	0.06	0.81	0.03	0.30	0.58
Theme:Trope	1	0.11	0.50	0.48	0.34	1.63	0.20	0.57	2.29	0.13	0.12	0.58	0.45	0.09	0.02	0.89	0.08	0.69	0.41
Genre:Trope	1	0.00	0.02	0.90	0.25	1.20	0.27	0.03	0.12	0.73	0.31	1.55	0.21	0.68	0.16	0.69	0.21	1.96	0.16
Residuals	243	0.22			0.21			0.25			0.20			4.30			0.11		

Table 7. Participant Comprehension Results (in two parts). The table shows descriptive statistics (top half of each part) and factorial ANOVA (bottom half) for comprehension. The table includes main effects by factor (theme, genre, and trope) as well as interaction effects between factors. The table includes nine separate factorial ANOVA models on comprehension for each of the nine evaluated narrative elements and two additional models for total comprehension across all elements and mistakes in comprehension. Color indicates significance: $p < 0.10$, $p < 0.05$, $p < 0.01$, $p < 0.001$.

Factor / Interactions		Interest+ (Interest)			Interest- (Concern)			Belief+ (Agree)			Belief- (No Influence)		
Descriptive	n		mean	sd		mean	sd		mean	sd		mean	sd
Total	2000		5.0	1.7		4.5	1.9		5.0	1.6		3.8	1.9
US presidential campaign donations	1000		5.1	1.6		4.9	1.8		5.2	1.5		3.6	1.9
US sea-level rise	1000		4.8	1.8		4.0	1.9		4.8	1.6		4.0	1.8
Longform infographics	1008		5.1	1.6		4.4	1.9		5.2	1.5		3.6	1.8
Dynamic slideshows	992		4.9	1.8		4.5	1.9		4.8	1.6		4.0	2.0
Leader lines	1000		5.2	1.7		4.6	1.8		5.1	1.6		3.6	1.9
Color highlighting	1000		4.8	1.7		4.3	1.9		4.9	1.5		3.9	1.9
Factorial ANOVA	df	Mean Sq	F	p	Mean Sq	F	p	Mean Sq	F	p	Mean Sq	F	p
Theme	1	4.62	1.62	0.21	46.66	14.01	0.00	10.82	4.57	0.03	7.40	2.10	0.15
Genre	1	1.61	0.56	0.45	0.48	0.14	0.71	7.74	3.27	0.07	11.05	3.14	0.08
Trope	1	12.19	4.26	0.04	5.60	1.68	0.20	3.79	1.60	0.21	5.77	1.64	0.20
Theme : Genre	1	0.08	0.03	0.87	2.35	0.71	0.40	0.00	0.00	0.97	7.66	2.17	0.14
Theme : Trope	1	1.87	0.65	0.42	8.28	2.49	0.12	4.34	1.83	0.18	0.62	0.18	0.68
Genre : Trope	1	13.79	4.81	0.03	3.74	1.12	0.29	0.08	0.03	0.85	2.06	0.58	0.45
Residuals	243	2.86			3.33			2.37			3.52		

Factor / Interactions		Arousal+ (Excite)			Arousal- (Bore)			Hedonic+ (Enjoy)			Hedonic- (Upset)		
Descriptive	n		mean	sd		mean	sd		mean	sd		mean	sd
Total	2000		3.5	1.7		3.1	1.9		4.4	1.8		3.2	1.8
U.S. presidential campaign donations	1000		3.5	1.7		3.0	1.9		4.4	1.7		3.5	2.0
U.S. sea-level rise	1000		3.5	1.7		3.1	1.9		4.3	1.8		2.9	1.7
Longform infographics	1008		3.3	1.6		2.9	1.8		4.4	1.7		2.9	1.8
Dynamic slideshows	992		3.7	1.7		3.3	2.0		4.3	1.8		3.5	1.9
Leader lines	1000		3.6	1.7		2.9	1.8		4.5	1.7		3.2	1.9
Color highlighting	1000		3.4	1.6		3.2	1.9		4.2	1.8		3.1	1.8
Factorial ANOVA	df	Mean Sq	F	p	Mean Sq	F	p	Mean Sq	F	p	Mean Sq	F	p
Theme	1	0.04	0.01	0.91	0.48	0.14	0.71	0.58	0.19	0.67	23.72	7.24	0.01
Genre	1	7.73	2.76	0.10	9.67	2.78	0.10	0.34	0.11	0.74	21.52	6.57	0.01
Trope	1	3.83	1.37	0.24	6.01	1.72	0.19	4.55	1.47	0.23	0.92	0.28	0.60
Theme : Genre	1	0.16	0.06	0.81	2.30	0.66	0.42	0.19	0.06	0.80	1.60	0.49	0.49
Theme : Trope	1	0.50	0.18	0.67	4.72	1.35	0.25	2.21	0.72	0.40	0.99	0.30	0.58
Genre : Trope	1	4.78	1.71	0.19	5.16	1.48	0.23	9.08	2.94	0.09	0.63	0.19	0.66
Residuals	243	2.80			3.49			3.09			3.28		

Table 8. Participant Reaction Results (in two parts). The table shows descriptive statistics (top half of each part) and factorial ANOVA (bottom half) for reaction. Likert ratings are out of 7 points. The table includes main effects by factor (theme, genre, and trope) as well as interaction effects between factors. The table includes eight separate factorial ANOVA models on reaction, one for each of the evaluated reaction measures. Color indicates significance: $p < 0.10$, $p < 0.05$, $p < 0.01$, $p < 0.001$.

Individual Difference		A: Influence on Retention						B: Influence on Comprehension					
		Sea-level rise		Presidential campaign donations		Both		Sea-level rise		Presidential campaign donations		Both	
Relation to Visual Story Theme		β	p	β	p	β	p	β	p	β	p	β	p
Expertise: Familiarity	Environment and Science	-0.28	0.24					0.08	0.68				
	Domestic Politics			0.38	0.13					-0.09	0.69		
Expertise: Training	Environment and Science	-0.15	0.39					-0.42	0.01				
	Domestic Politics			-0.06	0.77					-0.12	0.52		
Motivation: Prior Interest	Environment and Science	0.04	0.84					-0.18	0.29				
	Domestic Politics			-0.28	0.24					0.20	0.33		
Prior Beliefs	Socially liberal-v-conservative	0.26	0.08					-0.18	0.15				
	Fiscally liberal-v-conservative			0.20	0.19					0.00	0.98		
	Environmentally conscious-v-agnostic	-0.37	0.03					-0.34	0.02				
	Politically active-v-agnostic			-0.22	0.24					-0.05	0.76		
	Concern about sea-level rise	-0.47	0.01					-0.44	0.01				
	Concern about coastal vulnerable properties												
	Concern about presidential campaign donations			0.07	0.69								
	Concern about the presidential election results									-0.12	0.40		
	I believe sea-level rise is a topic worth discussing	0.39	0.08										
	I believe presidential campaign donation is a topic worth discussing			0.10	0.62			0.41	0.03				
	I believe sea-level rise is a problem									0.29	0.10		
	I believe presidential election campaign donation is a problem												
Relation to Design and Technology		β	p	β	p	β	p	β	p	β	p	β	p
Expertise: Familiarity	Print News Sources	0.23	0.11	0.31	0.11	0.57	0.01	-0.16	0.29	-0.13	0.45	-0.32	0.10
	Online News Sources	-0.65	0.01	-0.77	0.01	-1.20	0.00	-0.58	0.01	-0.56	0.02	-0.89	0.00
	Maps	-0.35	0.27	-0.26	0.27	-0.51	0.04	0.02	0.92	-0.12	0.55	0.12	0.59
	Computing Technology	-0.00	0.59	-0.13	0.59	-0.37	0.17	-0.22	0.25	-0.21	0.31	-0.57	0.02
	The Internet	0.56	0.00	0.96	0.00	1.51	0.00	0.18	0.47	0.38	0.17	0.71	0.03
	Information Graphics	0.34	0.72	0.08	0.72	0.45	0.09	0.24	0.18	0.28	0.17	0.44	0.07
Expertise: Training	Print News Sources	-0.13	0.43	0.23	0.26	-0.05	0.82	-0.02	0.89	0.22	0.20	0.04	
	Online News Sources												0.826
	Maps	-0.13	0.47	-0.47	0.02	-0.63	0.00	0.12	0.44	-0.09	0.63	-0.25	
	Computing Technology												0.20
	The Internet	0.26	0.07	-0.13	0.42	0.06	0.71	0.25	0.04	0.11	0.41	0.16	
	Information Graphics												0.304
Motivation: Prior Interest	Print News Sources	-0.32	0.09	-0.53	0.01	-0.80	0.00	-0.27	0.09	-0.31	0.09	-0.37	0.07
	Online News Sources	0.55	0.01	0.58	0.01	1.07	0.00	0.63	0.00	0.39	0.05	1.05	0.00
	Maps	0.08	0.67	0.22	0.26	0.28	0.20	0.04	0.81	0.03	0.85	-0.04	0.86
	Computing Technology	-0.07	0.74	-0.01	0.97	0.16	0.55	-0.11	0.54	-0.04	0.85	0.06	0.81
	The Internet	0.14	0.59	0.26	0.37	0.37	0.26	0.12	0.57	0.13	0.60	0.31	0.29
	Information Graphics	0.22	0.29	0.23	0.31	0.32	0.20	-0.27	0.12	-0.21	0.27	-0.48	0.03

Table 9. Influence of Individual Differences on Retention and Comprehension. The table shows the results of multiple linear regression between individual differences and retention and comprehension. Color indicates significance: $p < 0.10$, $p < 0.05$, $p < 0.01$, $p < 0.001$. Yellow indicates an individual difference measure that we removed because it was collinear with another measure.

Individual Difference		Arousal+ The visual story excited me.		Arousal- The visual story bored me.		Hedonic+ I enjoyed the visual story.		Hedonic- I was upset by the visual story.		Interest+ The visual story interested me.		Interest- The visual story concern me.		Belief+ I agree with the visual story.		Belief- The visual story did not influence my views.	
Relation to Visual Story Theme		θ	p	θ	p	θ	p	θ	p	θ	p	θ	p	θ	p	θ	p
Expertise: Familiarity	Environment and Science OR Domestic Politics	0.93	0.60	1.33	0.03	0.80	0.09	0.76	0.03	0.71	0.01	0.73	0.02	0.81	0.11	1.39	0.01
Expertise: Training	Environment and Science OR Domestic Politics	1.15	0.19	1.25	0.03	1.07	0.49	1.08	0.50	0.98	0.85	1.10	0.33	1.09	0.40	1.12	0.28
Motivation: Prior Interest	Environment and Science OR Domestic Politics	1.11	0.38	0.89	0.29	1.02	0.85	1.37	0.01	1.15	0.24	1.09	0.46	0.92	0.46	0.94	0.59
Prior Beliefs	Socially liberal-v-conservative OR Fiscally liberal-v-conservative	0.99	0.92	1.06	0.47	1.15	0.08	1.18	0.03	1.04	0.59	1.10	0.26	0.93	0.35	0.97	0.67
	Environmentally conscious-v-agnostic OR Politically active-v-agnostic	1.10	0.33	1.14	0.18	1.25	0.02	0.98	0.80	1.09	0.37	1.07	0.53	1.14	0.11	1.06	0.56
	Concern about sea-level rise OR Concern about presidential campaign donations	1.07	0.48	1.13	0.20	1.10	0.32	1.18	0.09	1.05	0.60	1.33	0.00	1.24	0.03	0.91	0.33
	Concern about coastal vulnerable properties Concern about the presidential election results																
	I believe sea-level rise is a topic worth discussing OR I believe presidential campaign donation is a topic worth discussing	1.16	0.20	0.77	0.02	1.26	0.04	1.14	0.22	1.41	0.00	1.23	0.07	1.20	0.11	0.78	0.03
	I believe sea-level rise is a problem I believe Presidential election campaign donation is a problem																
Relation to Design and Technology		θ	p	θ	p	θ	p	θ	p	θ	p	θ	p	θ	p	θ	p
Expertise: Familiarity	Print News Sources	0.98	0.88	0.95	0.58	0.99	0.90	1.02	0.90	1.10	0.34	0.94	0.55	0.93	0.50	1.06	0.61
	Online News Sources	1.02	0.91	0.92	0.57	1.50	0.01	1.00	0.98	1.15	0.36	0.81	0.15	1.16	0.30	1.19	0.24
	Maps	0.56	0.00	1.17	0.23	0.73	0.02	1.24	0.09	0.81	0.11	1.11	0.41	0.92	0.53	1.12	0.40
	Computing Technology	0.83	0.16	1.22	0.11	0.94	0.64	1.25	0.07	1.00	0.99	1.03	0.85	0.79	0.07	1.21	0.12
	The Internet	0.91	0.57	0.95	0.77	0.77	0.13	0.88	0.42	0.80	0.19	1.05	0.76	0.96	0.82	0.84	0.29
	Information Graphics	1.20	0.15	0.94	0.56	0.90	0.44	0.89	0.34	1.01	0.95	1.15	0.25	1.33	0.02	0.69	0.00
Expertise: Training	Print News Sources	0.86	0.15	1.01	0.90	0.87	0.16	1.13	0.24	0.94	0.53	1.03	0.77	0.93	0.48	1.01	0.89
	Online News Sources																
	Maps	1.26	0.04	0.80	0.05	1.04	0.70	0.92	0.45	1.06	0.59	1.01	0.90	1.06	0.58	0.89	0.26
	Computing Technology																
	The Internet	0.98	0.81	1.18	0.06	1.00	1.00	1.01	0.87	1.00	0.97	0.96	0.61	1.00	0.98	1.11	0.21
	Information Graphics																
Motivation: Prior Interest	Print News Sources	1.38	0.00	0.99	0.94	1.15	0.21	1.12	0.34	1.13	0.26	1.18	0.15	1.18	0.14	0.87	0.20
	Online News Sources	1.06	0.64	0.95	0.70	1.11	0.41	0.90	0.40	1.03	0.81	1.03	0.79	0.93	0.55	0.93	0.54
	Maps	1.20	0.09	0.75	0.01	1.41	0.00	0.91	0.39	1.42	0.00	1.10	0.36	1.27	0.02	0.93	0.47
	Computing Technology	1.02	0.88	0.78	0.04	1.00	1.00	0.84	0.16	1.14	0.30	1.16	0.23	1.18	0.20	0.81	0.09
	The Internet	0.89	0.48	0.96	0.74	1.04	0.80	0.87	0.36	1.15	0.39	0.95	0.77	1.56	0.01	0.85	0.32
	Information Graphics	1.35	0.01	0.96	0.70	1.40	0.01	1.06	0.65	0.96	0.76	0.96	0.76	0.80	0.06	1.04	0.77

Table 10. Influence of Individual Differences on Reaction. The table shows the results of multiple linear regression between individual differences and reaction. Color indicates significance: $p < 0.10$, $p < 0.05$, $p < 0.01$, $p < 0.001$. Yellow indicates an individual difference measure that we removed because it was collinear with another measure.

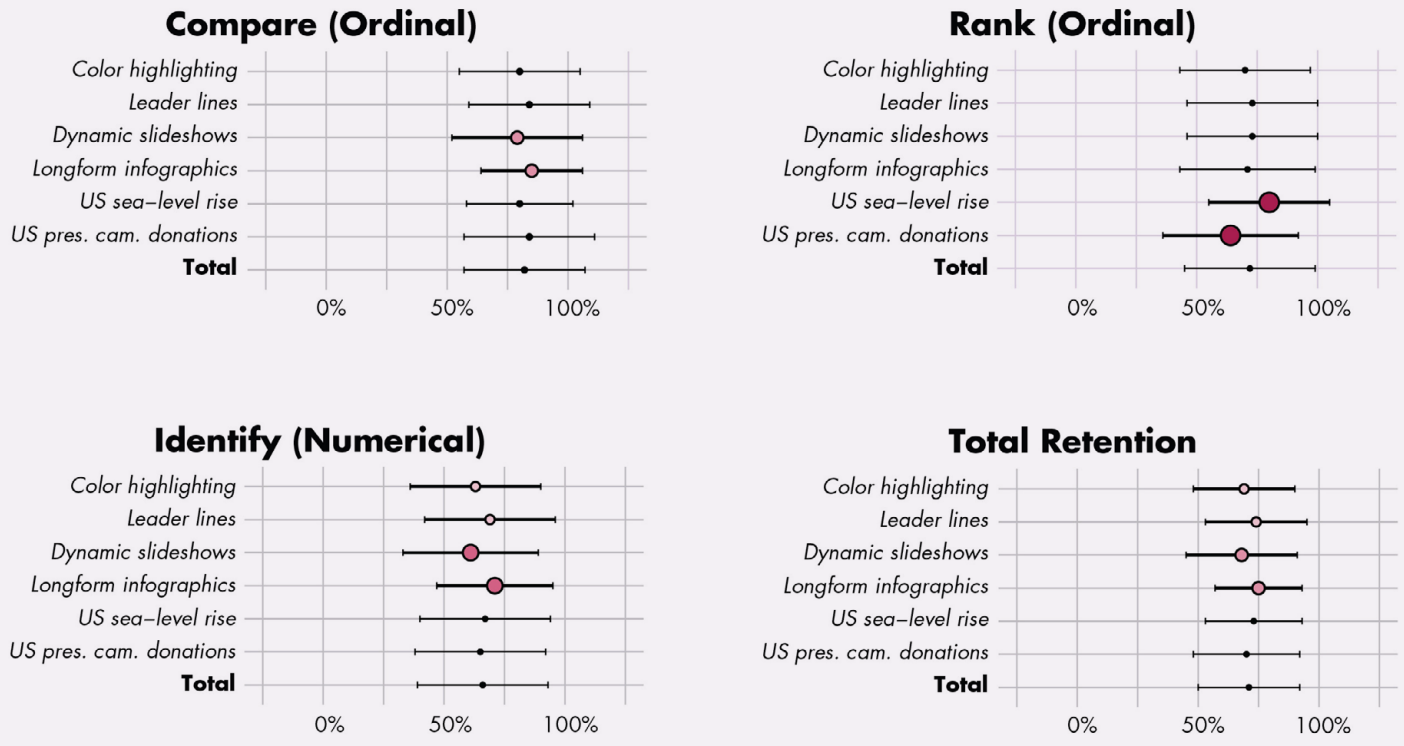

Figure 4. Retention Scores by Factorial Conditions. Color indicates significance: $p < 0.10$, $p < 0.05$, $p < 0.01$, $p < 0.001$. Size is used redundantly with color shading to indicate significance.

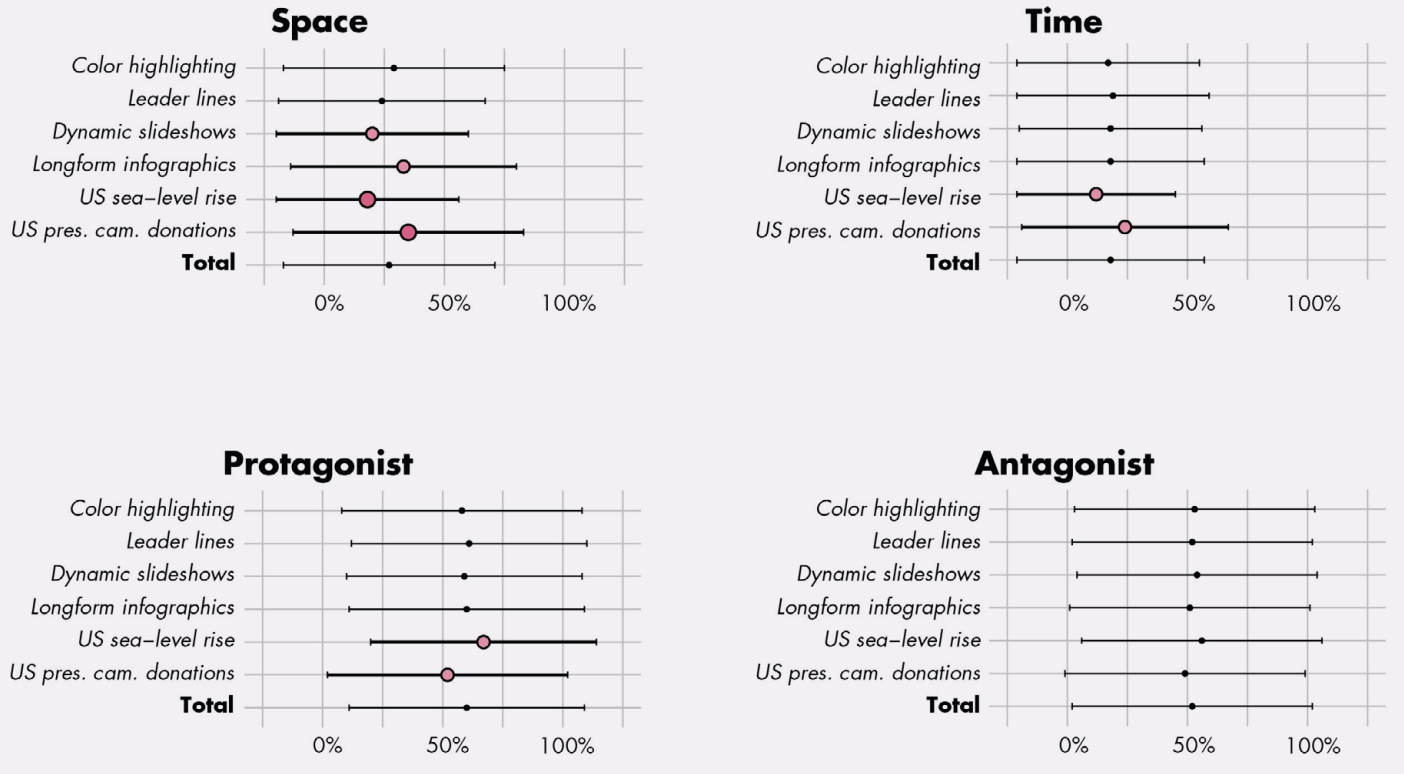

Figure 5. Comprehension Scores by Factorial Conditions. Color indicates significance: $p < 0.10$, $p < 0.05$, $p < 0.01$, $p < 0.001$. Size is used redundantly with color shading to indicate significance. Figure continues on the next page.

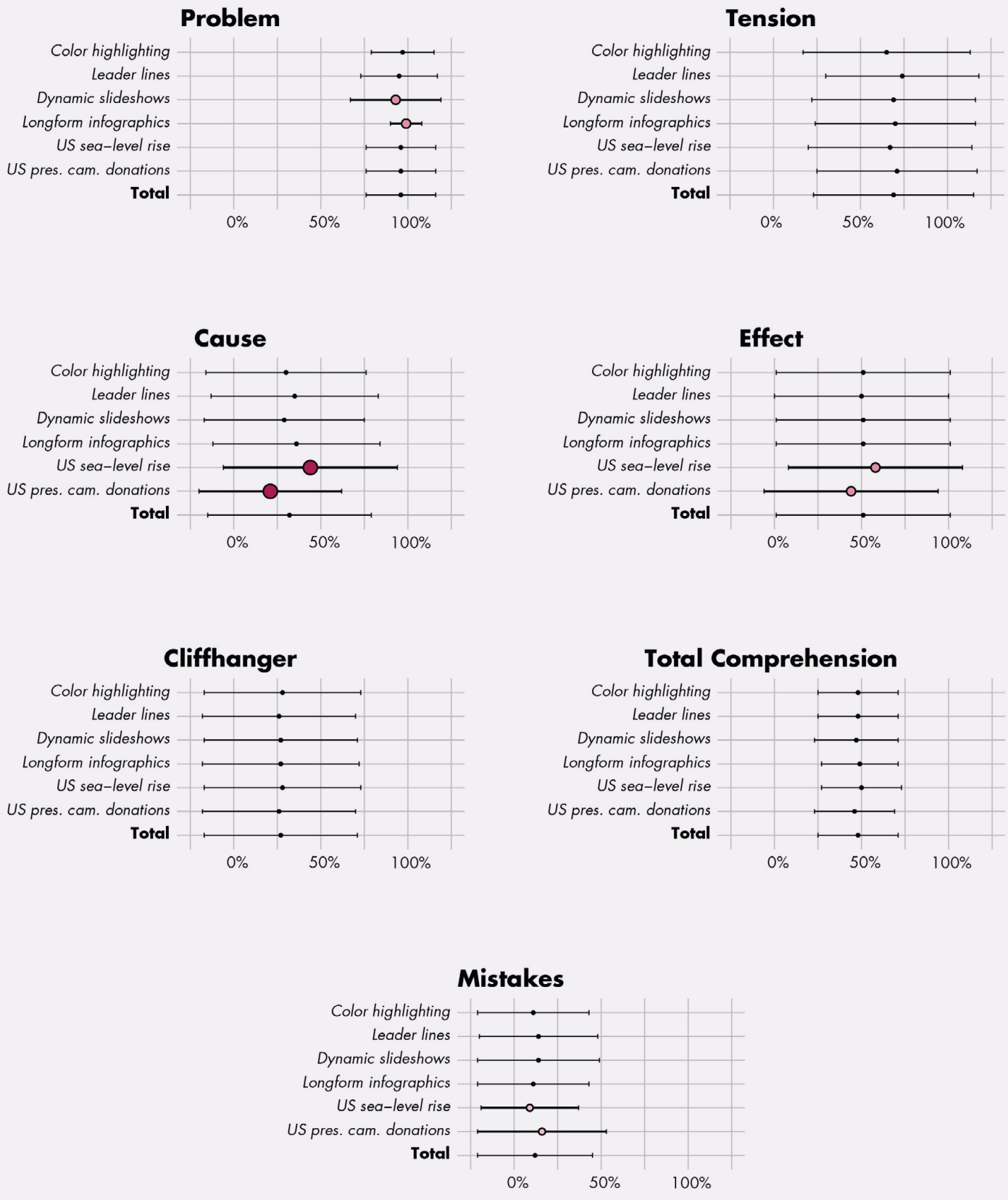

Figure 5 (continued). Comprehension Scores by Factorial Conditions. Color indicates significance: $p < 0.10$, $p < 0.05$, $p < 0.01$, $p < 0.001$. Size is used redundantly with color shading to indicate significance.

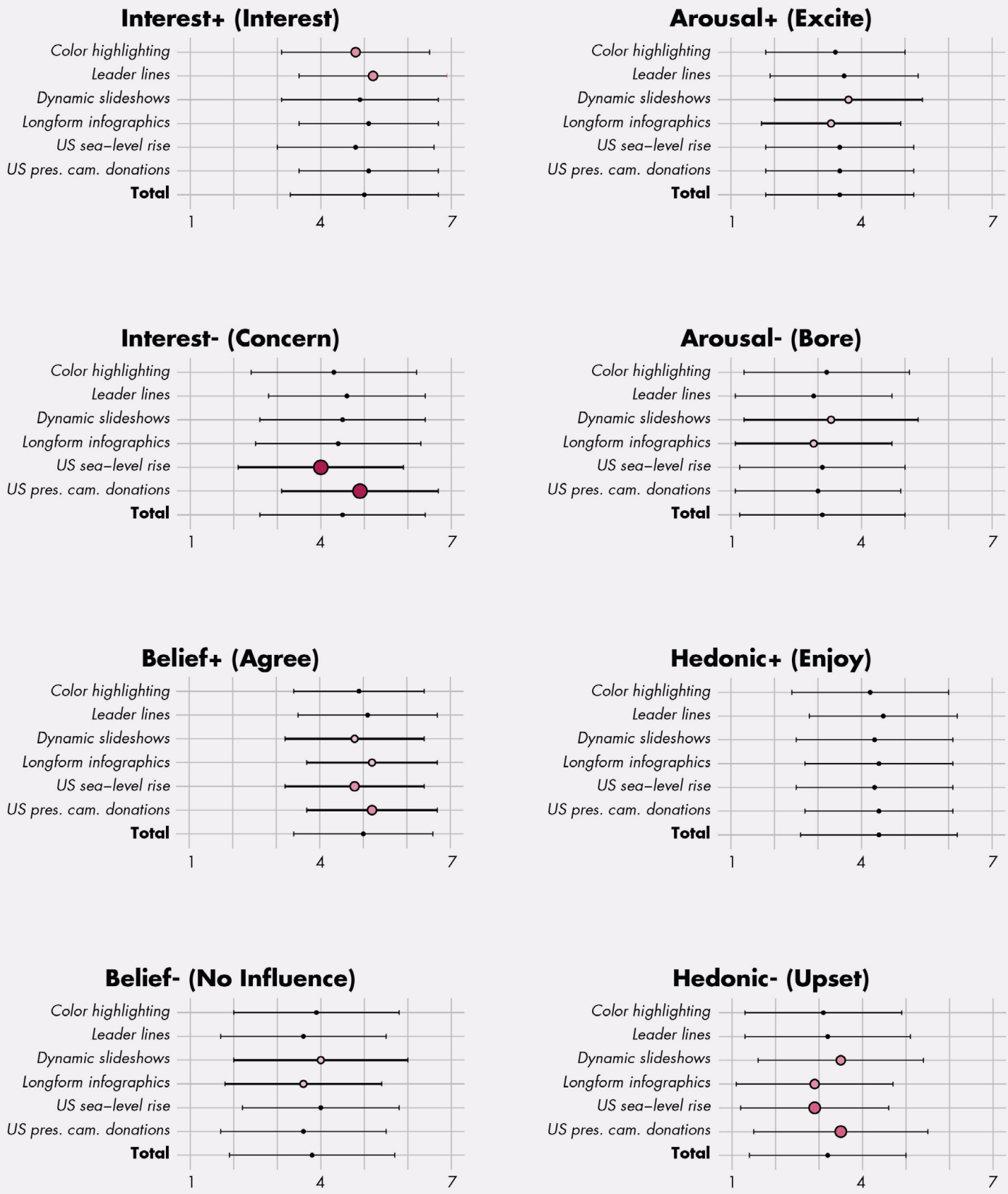

Figure 6. Reaction Scores by Factorial Conditions. Color indicates significance: $p < 0.10$, $p < 0.05$, $p < 0.01$, $p < 0.001$. Size is used redundantly with color shading to indicate significance.

RESULTS AND DISCUSSION

OVERALL RESULTS

Participants completed retention questions with an overall accuracy of 71.4%, suggesting that the retention questions were neither obvious nor impossible (**Table 6**). As expected, participants performed the best on the simpler compare (ordinal) tasks (81.9%) and worst on the more difficult to remember identify (numerical) tasks (66.2%), with the accuracy for rank (ordinal) tasks in the middle (71.7%).

Regarding comprehension, participants on average described 48.0% of the narrative elements included in the comprehension coding scheme (**Table 7**), a relatively rich discussion about the tested stories given the general audience recruited from Mechanical Turk and open-ended format of the comprehension question. In contrast, only 12.4% of the responses included a mistake in comprehension. Thus, comprehension results generally showed that three-act narrative structure was effective for map-based visual storytelling. There were several notable patterns in overall comprehension that provide insight into the visual design of elements in a three-act narrative. Nearly all participants (96.0%) clearly stated the problem of the story in their comprehension response, suggesting that the problem was the most salient narrative element in both visual story themes. Although an expected finding, confirmation that readers focused 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 three next most commonly mentioned codes related to the characters in the story: 69.2% of participants described the tension—or the how the problem impacts the key characters—59.6% described the protagonist, and 52.4% described the antagonist. This suggests that the focus attention strategies applied to the characters were relatively successful (although differentially so by condition, as described in the results by tropes below). This description also provided evidence that readers can conceptualize places or regions as characters in an explicitly geographic story, presenting an opportunity to add dramatic narrative structuring to map designs in visual stories. While both stories used Phillip's (2012) cause and effect narrative structure, the cause (32.4%) was discussed much less frequently than the effect (50.8%), showing a bias towards outcomes compared to drivers in visual story comprehension. Finally, spatial setting (26.5%), the cliffhanger (26.8%), and temporal setting (18.0%) 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 it is possible that the visual accenting of specific place-based characters diverted attention away from the overall spatiotemporal context.

The two strongest reaction registers to the visual stories were on interest and agreement, receiving an average response of 5.0/7 for both measures (**Table 8**). Thus, overall the visual stories captured participant interest—demonstrating the value of employing maps and graphics for visual storytelling—and participants generally agreed with the cause/effect narrative used to structure the story. Participants also provided slightly positive ratings for their concern about the story topic (4.5/7), but nearly neutral ratings about the story's influence on them (3.8/7). 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 of 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).

STORY MAP THEMES (FACTOR 1)

Factor 1 included two conditions by visual storytelling theme: *US presidential campaign donations* and *US sea-level rise*. Starting with retention (**Table 6**), there was no statistical difference between themes regarding total retention ($F = 2.03$, $p = 0.16$). Thus, the theme did not impact the "accuracy" or "correctness" of reading the maps and graphics in the visual story, common metrics used in empirical map design research. This is a potentially exciting finding for cartographers and data journalists, suggesting that the visualized theme may not influence story retention for a general audience if the design follows a three-act narrative structure. Looking at specific retention questions, there were no significant differences between themes with regard to the easy compare (ordinal) tasks ($F = 2.44$, $p = 0.12$) and the difficult identify (numerical) tasks ($F = 0.27$, $p = 0.60$). However, there was a significance difference

between themes in retention for the rank (ordinal) tasks (F = 25.12, p = 0.00) as well as a significant interaction effect between theme and tropes for rank (ordinal) tasks (F = 4.01, p = 0.05). The interaction possibly could be attributed to the phrasing of sea-level "rise" for the *US sea-level rise* condition, which may have suggested an increasing trend, thus requiring fewer visual cues to focus attention on to the highest ranked year (see **Supplemental Materials**).

Similarly, there was no statistical difference in total comprehension between themes in the average number of narrative elements discussed (F = 1.21, p = 0.27; **Table 7**), adding evidence that the visualized theme may not influence performance for a general audience if the design follows a three-act narrative structure. However, participants made more mistakes in comprehension for the *US presidential campaign donations* condition (16.0%) than the *US sea-level rise* condition (8.8%), a significant difference at alpha = 0.10 (F = 2.98, p = 0.09), potentially pointing to prior misconceptions about the 2016 US presidential election. There also were several notable differences in comprehension between themes for specific narrative elements. Participants discussed the spatial (F = 10.49, p = 0.00) and temporal (F = 6.23, p = 0.01) settings significantly more frequently in their open-ended responses for the *US presidential campaign donations* story than the *US sea-level rise* story. In contrast, participants discussed the cause (F = 16.36, p = 0.00) and effect (F = 4.63, p = 0.03) more frequently for the *US sea-level rise* story than the *US presidential campaign donations* story. While there may be a variety of explanations for these differences by specific narrative elements, we suspect that the setting ("swing states") was implicitly more central to understanding the *US presidential campaign donations* story and the cause-effect relationship ("climate change") was implicitly more central to understanding the *US sea-level rise* story, despite controlling the information and design complexity for these narrative elements in both visual stories. Thus, while the theme did not influence total comprehension, individual themes and unique visual story designs of these themes are likely to lend themselves better to some narrative elements over others. We also found a significant difference in comprehension for the protagonist (F = 6.02, p = 0.01), which might be a slight bias in recall for New York generally (the protagonist in the *US sea-level rise story*), a populous US state often dominating media coverage. Significant differences in comprehension were not observed for other narrative elements.

Interestingly, participants appeared to have a somewhat stronger reaction to the *US presidential campaign donations* story than the *US sea-level rise* story, although significant differences were not observed for all reaction metrics (**Table 8**). The largest difference in reaction between themes regarded participant concern: participants overall were concerned by the *US presidential campaign donation* story (4.9/7), but were neither concerned nor unconcerned with the *US sea-level rise* story (4.0/7), a significant difference at alpha = 0.01 (F = 14.01, p = 0.00). Participants also were more upset by the *US presidential campaign donation* story (3.5/7) than the *US sea-level rise* story (2.9/7), a significant difference at alpha = 0.01 (F = 7.24, p = 0.01), although on average both sets of participants disagreed with the statement (below 4.0/7) and therefore these ratings should be interpreted as a greater apathy towards the *US sea-level rise* story. Participants ultimately agreed more with the *US presidential campaign donation* story than the *US sea-level rise* story (F = 4.57, p = 0.03), perhaps because of the increased hedonic reaction to the former story. The influence of the story theme on participant reaction is possibly explained by the timing of the study, which was conducted four months after the polarizing presidential election of 2016. In contrast, sea-level rise and climate change broadly work on a longer time scale and within less well-defined geographic boundaries, a noted challenge for science communication in getting the public to care about climate change and its effects (Fish 2020a). Reaction differences by theme also may be explained by the fiscally and socially liberal lean in the participant sample (**Figure 1**), as the *US presidential campaign donation* story had a subtle conservative lean (the relationship between political leaning and reaction concern is discussed in more detail under individual differences). There was no statistical difference in other reaction metrics.

VISUAL STORYTELLING GENRE (FACTOR 2)

Factor 2 included two conditions by visual storytelling genre: *longform infographics* and *dynamic slideshows*. Unlike themes, overall differences in retention by genres were statistically significant (F = 5.47, p = 0.02) (**Table 6**). Participants correctly answered 74.5% of retention questions for visual stories presented as *longform infographics*, but only 68.3% for visual stories containing the same content but presented as *dynamic slideshows*. Thus, it was the technique used to enforce continuity across narrative elements (i.e., genres), and not the element content itself (i.e., themes), that influenced retention, with participants

having greater difficulty remembering information from dynamic slideshows. This is an important finding for cartography and visual storytelling, as well as science communication and pedagogy generally, as visual material more commonly is presented as a discrete slide deck instead of a continuous graphic or webpage in educational settings and public presentations. Further, this finding points to the relevance of emerging design strategies made possible by new media for map-based visual storytelling, as *longform infographics* enable scrolling at an audience-controlled pace, whereas *dynamic slideshows* dose information at a designer-controlled pace. We found significant differences for the easier compare (ordinal) tasks ($F = 4.01$, $p = 0.05$) and more difficult identify (numerical) tasks ($F = 8.52$, $p = 0.00$) tasks, but not for the intermediate-difficulty rank (ordinal) tasks ($F = 0.26$, $p = 0.61$), perhaps because of the aforementioned interaction effect for rank (ordinal) tasks between theme and tropes.

Regarding comprehension, participants described 49.4% of the total narrative elements when the story was presented as *longform infographics* but only 46.6% when presented as *dynamic slideshows*, again indicating better performance with *longform infographics*. However, this was not a significant difference ($F = 0.92$, $p = 0.34$; **Table 7**), and overall we observed fewer comprehension differences by genres than theme for individual narrative elements. Interestingly, there was a significant difference by genres in discussion of the problem ($F = 6.82$, $p = 0.01$): while nearly all (99.2%) participants discussed the problem when viewing *longform infographics*, only 92.7% of participants discussed the problem when viewing *dynamic slideshows*. 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 in comprehension. Thus, while the retention measures indicated that the *dynamic slideshows* inhibited recall of specific numbers for many participants, the comprehension measures indicated that the *dynamic slideshows* inhibited development of a general problem understanding for small set of participants, together representing the "worst of both worlds." One potential explanation for the observed poorer retention and comprehension for *dynamic slideshows* is the manner in which they enforce continuity: clicking through the frames in *dynamic slideshows* interrupted the flow of the story, requiring reloading of new content that may be exacerbated due to bandwidth lags, altogether breaking audience concentration. Relatedly, participants discussed the spatial setting significantly more frequently when viewing *longform infographics* (32.5%) versus *dynamic slideshows* (20.3%), possibly because they could more readily access maps—included on only four of nine panels—through quick scrolling upwards versus reloading a prior slide. There was not a significant difference in the number of comprehension mistakes or for other comprehension codes between genres.

Genres did have a marginal impact on participant reaction (**Table 8**), although most differences were significant only at alpha = 0.10. Participants were more likely to believe ($F = 3.27$, $p = 0.07$) and more likely to have their views influenced by ($F = 3.14$, $p = 0.08$) stories when presented as *longform infographics* versus *dynamic slideshows*, an indication of increased influence and trust evoked by the emerging "scrollytelling" genre. Notably, participants reported feeling more upset when viewing *dynamic slideshows* than the *longform infographics* ($F = 6.57$, $p = 0.01$), a significant difference at alpha = 0.05. The negative hedonic reaction scale did not distinguish between the visual story content versus design ("I was upset by the visual story"), and it is possible the unpleasant reaction to *dynamic slideshows* is because of the broken experience of the discrete slide advance. However, this broken nature also may generate more suspense and anxiety, a characteristic of *dynamic slideshows* that may be useful when the story topic and framing require a congruently negative affective response (Anderson and Robinson 2022). Finally, *dynamic slideshows* were rated as both more exciting ($F = 2.76$, $p = 0.10$) and more boring ($F = 2.78$, $p = 0.10$) than *longform infographics*, a somewhat contradictory finding possibly indicating that *dynamic slideshows* garner a wider variety of reactions from the audience.

Notably, Factor 2 was assigned between subjects, unlike Factors 1 and 3, and therefore the results by genre may be influenced by potential imbalances in sampling (see **Supplemental Materials**). Participants who viewed *longform infographics* reported a greater interest in the internet (6.3/7 versus 5.2/7 for *dynamic slideshows*), computing technology (5.7/7 versus 4.5/7), and online news (5.1/7 versus 4.3/7), and a greater familiarity with computing technology (5.6/7 versus 4.8/7). Thus, the generally observed benefit of *longform infographics* instead may be explained by increased participant motivation derived from greater interest and familiarity with internet and computing technologies. In contrast, participants who viewed *dynamic slideshows* reported greater training in the internet (5.2/7 versus 4.4/7 for *longform infographics*), environment

and science (4.1/7 versus 2.8/7), online news (4.2/7 versus 3.0), domestic politics (3.9/7 versus 2.4/7), information graphics (3.7/7 versus 2.8/7), maps (3.8/7 versus 2.9/7) and print news (3.4/7 versus 2.6/7). Thus, maps and visual storytelling generally were less novel for participants assigned to *dynamic slideshows* and therefore this could have influenced motivation, prior expectations, and, accordingly, performance with *dynamic slideshows*. Sampling by domain-specific characteristics not captured through participant demographics is difficult to manage through Mechanical Turk, and thus future research with purposeful participant recruitment is needed to investigate how well the observed differences by genre apply across different levels of interest, familiarity, and training.

VISUAL STORY TROPE (FACTOR 3)

Factor 3 included two conditions by visual storytelling trope, with both conditions employing a visual accenting technique for focusing attention: *leader lines* and *color highlighting*. Differences in retention by tropes were statistically significant at alpha = 0.10 ($F = 3.51$, $p = 0.06$; **Table 6**). Participants correctly answered 73.8% of retention questions for visual stories using *leader lines* as the focus attention strategy, but only 69.1% using *color highlighting*. While a weaker influence on retention than the genres condition in our study, the difference by tropes extends the Griffin and Robinson (2015) study in the context of visual accenting between coordinated representations, suggesting that *leader lines* are not only a viable alternative to *color highlighting* when color needs to be used elsewhere in design, but actually are a more salient focusing attention technique generally. There were no significant differences by tropes for the easier compare (ordinal) ($F = 1.83$, $p = 0.18$) or rank (ordinal) ($F = 1.19$, $p = 0.28$) retention questions, but differences by tropes for the more difficult identify (numerical) task were significant at alpha = 0.10 ($F = 3.28$, $p = 0.07$). Thus, the benefit of *leader lines* over *color highlighting*—and thus more salient focusing attention techniques—may increase as the difficulty in the task grows.

Tropes did not result in a significant difference in total comprehension ($F = 0.11$, $p = 0.74$), the number of comprehension mistakes ($F = 0.29$, $p = 0.59$), or any specific narrative element (**Table 7**). We were surprised that none of the tested factors resulted in significant differences in total comprehension. Although we found the comprehension discussion surprisingly rich, with participants on average describing 48.0% of the narrative elements, the simplicity of the comprehension question prompt and the online format of the survey perhaps limited the response length. Greater depth in comprehension instead may be elicited through alternative social science methods such as cognitive walkthroughs, think aloud studies, and post-hoc interviews and focus groups. However, our method did present an opportunity to investigate how the visual story design influenced discussion of the more important or obvious narrative elements in their shorter qualitative responses, resulting in the significant differences by themes and tropes for individual narrative elements described above.

The trope conditions did result in a significant difference in participants' reported interest in the visual story ($F = 4.25$, $p = 0.04$; **Table 8**). Participants reported being more interested in visual stories using *leader lines* (5.2/7) to focus attention than *color highlighting* (4.8/7). "Interest'" suggests an activated affective state, and while we did not observe a significant difference in positive arousal (which uses the more suggestive word "excited" to describe reaction), increased interest in a visual story is a marked benefit of using focusing attention techniques in visual story design: in this case, *leader lines* better focused audience attention on important or unusual information in the story, avoiding distraction from other design elements or split attention with other tasks. There also was a significant interaction in reported interest between the genre and tropes factors ($F = 4.81$, $p = 0.03$), indicating that participants were most interested in visual stories using a combination of *longform infographics* and *leader lines* regardless of the theme. Again, this is a useful finding for cartographers and data journalists, as the specific theme may not influence the interest garnered from a general audience as long as the visual story follows empirically-derived design recommendations for a three-act narrative, genres, and tropes. There were no addition significant differences by tropes in the other participant reaction scales.

INDIVIDUAL DIFFERENCES

Finally, the exit survey collected a number of measures of individual differences, including expertise, motivation, and prior beliefs. Examination of individual differences identified many interaction effects on retention, comprehension, and reaction. Our discussion below focuses on the most prominent patterns.

Regarding retention, the relationship of individuals to technology and design was a stronger driver than their relationship to the theme or their prior beliefs (**Table 9**). In particular, participants with greater familiarity with the internet ($\beta = 1.51$, $p = 0.00$) retained significantly more information from the visual stories than their counterparts. This signals an important consideration for data journalism and visual storytelling, as differential familiarity (i.e., expertise) with the online delivery format of the map study may have impacted results, with participants unfamiliar with internet technology retaining less information from the online stories.

There was an interesting tradeoff in retention between familiarity and interest in print versus online news sources. Participants with interest in online news sources ($\beta = 1.07$, $p = 0.00$) retained significantly more information than their counterparts, while participants with interest in print news sources retained significantly less than their counterparts ($\beta = -0.80$, $p = 0.00$). Familiarity with online news sources ($\beta = -1.20$, $p = 0.00$) and print news sources ($\beta = 0.57$, $p = 0.00$) reflected an inverse pattern. While future research is needed to track and confirm this effect by individual differences, the results possibly suggest that performance with online visual stories is influenced by interest in online versus print news sources broadly, but also suggest a possible tendency to skim visually as familiarity with online news sources increases.

In contrast, the relationship of individuals to the theme and their prior beliefs was a stronger relative driver of comprehension than their relationship to technology and design (**Table 9**). As with retention, participants with increased familiarity with the internet ($\beta = 0.71$, $p = 0.03$) and interest in online news sources ($\beta = 1.05$, $p = 0.00$) comprehended the visual stories significantly better than their counterparts, although this effect was smaller than with retention. While increased familiarity with online news stories decreased comprehension ($\beta = -0.89$, $p = 0.00$), similar to retention, there were no observed effects from familiarity or interest in print news sources on comprehension.

Instead, increased prior beliefs that sea-level rise is a topic worth of discussion ($\beta = 0.41$, $p = 0.03$) led to increased comprehension with the *US sea-level rise* theme. Interestingly, increased participant training in environment and science ($\beta = -0.42$, $p = 0.01$) led to reduced comprehension about the *US sea-level rise* theme, suggesting that participants with some expertise about the theme actually gleaned fewer specific details from the visual stories, instead relying on their prior understanding rather than drawing from specific evidence in the story. This is an interesting finding, as untrained, non-experts actually may approach visual stories more objectively, and thus consider new information and the overall narrative more thoroughly, as long as they believe the topic is worthy of discussion. It is arguable, however, that the subjectivity exhibited by experts may be an appropriate, hard-earned subjectivity, allowing them to discredit flawed or incomplete information and narratives more quickly. Unexpectedly, increased environmental consciousness and increased concern about sea-level rise both led to reduced retention and comprehension for the *US sea-level rise* theme, an apparent contradiction to prior beliefs that sea-level rise is a topic worth discussion.

We did not find any significant relationships between prior beliefs and retention or comprehension of the *US presidential campaign donations* condition. This perhaps is due to the polarizing nature of the 2016 US presidential election, but broadly indicates that the specific theme matters when considering individual differences.

While there are some notable interactions with retention and comprehension, individual differences appeared to have a greater influence on participant reaction to the visual stories (**Table 10**). There were several broad patterns between individual differences and reaction worth discussing.

First, familiarity and interest with maps and information graphics arguably had the largest influence on the reaction measures regarding participant relationships to technology and design. The more familiar participants were with maps, the less likely participants were excited by ($\theta = 0.56$, $p = 0.00$) or enjoyed ($\theta = 0.73$, $p = 0.02$) the visual stories, possibility suggesting that novelty in design plays a role in the reaction to map-based visual stories. However, greater interest in maps led to a decrease in boredom ($\theta = 0.75$, $p = 0.01$) with the visual stories and an increase in enjoyment ($\theta = 1.41$, $p = 0.00$), interest ($\theta = 1.42$, $p = 0.00$), and agreement with the visual stories ($\theta = 1.27$, $p = 0.02$). Similarly, greater interest in information graphics led to increased excitement ($\theta = 1.35$, $p = 0.01$) and enjoyment ($\theta = 1.40$, $p = 0.01$). Thus, individual differences in motivation around data-driven visuals like maps and graphics matter in the resulting reaction to visual stories containing these maps and graphics.

Second, with a few exceptions, familiarity with the story theme had a greater overall effect on reaction than training or interest in the topic. As with retention and comprehension, greater familiarity with the theme often resulted in a more negative reaction, as participants reported higher boredom (θ =1.33, p = 0.03) and maintenance of their beliefs about the topic (θ = 1.39, p = 0.01), as well as being less upset by (θ = 0.76, p = 0.03), interested in (θ = 0.71, p = 0.01), and concerned about (θ = 0.73, p = 0.02) the visual story when they had greater familiarity with the topic. While future research is needed to understand this relationship between expertise with and reaction to visual stories, these findings suggest that visual stories may evoke stronger positive reactions from general audiences less familiar with the story theme.

Third, as with comprehension, prior beliefs that the story theme was worth discussing did influence participant reaction. Participants more likely to find the topic worth discussing also were more likely to enjoy (θ = 1.26, p = 0.04) and be interested in (θ = 1.41, p = 0.00) the visual story as well as less likely to be bored by (θ = 0.77, p = 0.02) or maintain their beliefs about the visual story (θ = 0.78, p = 0.03). Thus, getting audiences to care about the topic is an important challenge—perhaps *the* challenge—in visual storytelling, as the way the audience values the topic before viewing the map appears to greatly influence how they subsequently react to the design and comprehend the depicted content. Unlike comprehension, this pattern does hold when reactions are pooled across the *US presidential campaign donations* and *US sea-level rise* themes.

CONCLUSION: IMPROVING THE DESIGN OF MAP-BASED VISUAL STORIES

In this paper, we reported on an empirical study to understand and improve the intentional design of map-based visual storytelling using a case study in data journalism. Compared to their popularity and wide reach, empirical research on map-based visual stories remains limited. The research reported here tackled four emerging design considerations for visual storytelling with maps: story map themes and their constituent three-act narrative elements, visual storytelling genres, visual storytelling tropes, and individual differences among the audience. Specifically, we asked four research questions to address emerging design considerations for visual storytelling:

1. ***What is the influence of story map themes and their constituent narrative elements on the audience's retention, comprehension, and reaction?*** Our study provided initial evidence that a three-act narrative and its constituent narrative elements can be applied consistently and effectively across visual story themes, and therefore offers new design opportunities for cartography and data journalism. Story map themes did *not* significantly influence total retention, the "accuracy" or "correctness" measure used in this study, or total comprehension, our alternative performance measure capturing additional dimensions of engagement and interest. This finding points to the need for establishing a research and education agenda on map-based visual storytelling in both cartography and data journalism, as the efficacy of some design decisions are based on not on the story content, but on the intentional design of the narrative structure and presentation. Interestingly, participants discussed the spatial and temporal setting significantly more frequently for the *US presidential campaign donations* story and the cause and effect more frequently for the *US sea-level rise* story, potentially indicating that, while themes may not influence total comprehension, some individual narrative elements may be more or less germane to understanding a given visual story. In contrast, story themes did influence audience reaction, with participants feeling significantly more concerned about and upset with the *US presidential campaign donations* story, and they ultimately agreed more with this story, perhaps because of the increased negative hedonic reaction. While not a direct goal of our study, this finding reinforces noted challenges for communication and action on climate change in the United States.

There are many opportunities for future research on narrative structures for map-based storytelling, three-act or otherwise. First, we tested two visual story themes using the same three-act narrative structure as a control to establish a baseline for three-act narrative design in cartography and also mitigate bias from current events or prior beliefs given the broader visual story design considerations in the factorial design. More research is

needed to test the baseline three-act narrative we described against alternative linear and non-linear narrative structures, as well as to isolate the influence of specific narrative elements within these structures to understand how they may be rearranged as narrative anchor points within a visual story. Further, we encourage comparison and evaluation of a wider range of Vujaković's (2014) visual story themes and Phillips's (2012) visual story structures, as well as correlation of how well these designs perform with individual differences. Finally, the three-act narrative structure relied mostly on static visuals, with user interactivity restricted to the genre mechanism for enforcing continuity in the factorial design (continuous scrolling versus discrete slide advancement). Extensions with interactivity range from martini-glass and reverse martini-glass narrative structures placing interactive maps at the bookends of the visual story (Segel and Heer 2010) to fully open-ended and user-controlled interactive digital narratives (Koenitz et al. 2015).

2. ***What is the influence of visual storytelling genres on the audience's retention, comprehension, and reaction?*** Visual storytelling genres *did* significantly influence total retention. *Longform infographics* outperformed *dynamic slideshows* for both retention and comprehension, although this difference was not significant for total comprehension. However, we did observe a significant difference in comprehension of the problem—the central confrontation, obstacle, or setback driving the story that formed perhaps the most important narrative element of the story—with nearly all participants discussing the problem in their open-ended responses when viewing *longform infographics*. Taken together, *dynamic slideshows* exhibited the worst of both worlds, causing participants to forget specific information (total retention) and, for some, to miss the overall point of the visual story (problem comprehension). The poorer performance with *dynamic slideshows* likely is attributed to the manner by which the genre enforces continuity and doses information, as *longform infographics* enabled continuous scrolling at an audience-controlled pace, whereas *dynamic slideshows* discretely dosed information in a designer-controlled pace. This finding also calls into question the optimal structure for dosing information in both research and teaching, given that material is commonly presented as a slideshow for in-person presentations. While the genre had a weaker influence on reaction than the story theme, participants were more upset with stories presented as *dynamic slideshows*, potentially an affective response attributed more to the broken nature of the genre structure than the story content.

   Our study suggests that choosing a storytelling genre as described by Segel and Heer (2010) and Roth (2021) is a nontrivial design decision, and thus warrants additional research in cartography, data journalism, and related fields. We examined just two visual storytelling genres and future research is needed to fully understand the relative advantages and limitations of each genre to inform their selection, content, and design. Notably, our findings contradict those of Wieczorek et al. (2014) on non-visual text presentation, where pagination (slideshows) outperformed scrolling (longform structure). We hypothesize that this could be attributed either to the inherently two-dimensional nature of maps versus one-dimensional text or the difference in control of dosing in our study versus the increased dosing of the pagination conditions in the Wieczorek et al. study. Regardless, future research is needed to evaluate different combinations of text and visuals like maps across genres, as well as to compare text, visuals, and other multimedia directly against one another as alternative story content within any given genre. As noted above, further research also is needed to investigate how well the observed differences by genre apply across different levels of audience interest, familiarity, and training.

3. ***What is the influence of visual storytelling tropes on the audience's retention, comprehension, and reaction?*** As with genres, the focus attention strategies (one visual storytelling trope) significantly influenced total retention, although only at alpha = 0.10. Retention significantly improved when narrative elements were accented by *leader lines* instead of *color highlighting*. While a weaker influence than genres, this finding extends Griffin and Robinson's (2015) recommendations for using leader lines for visual accenting across

multiple representations, as *leader lines* are not just an alternative to *color highlighting* when using color elsewhere in design, but actually are a more salient focusing attention technique generally. The benefit of *leader lines* over *color highlighting* increased as the question difficulty grew, suggesting more salient visual accenting techniques are needed as task complexity increases. As with other factors, there was not a significant difference in total comprehension between focus attention strategies, and we encourage adapting, extending, and triangulating alternative social science methods in the future to explore additional dimensions of audience comprehension. As with genres, tropes had a weaker influence on reaction than the story theme, but we did observe a significant difference in reported interest by tropes, with *leader lines* better focusing audience attention on important or unusual information in the story and avoiding distraction from other design elements or split attention with other tasks.

For future research, we encourage evaluation of the additional visual accenting techniques for focusing attention in visual storytelling compiled in Roth (2021), including comparing static solutions like flow arrows, appended geometric frames, opacity masks, numbering, call-outs, and labels, against dynamic solutions like blinking/flickering, panning/zooming, and focus+context visualizations. Further, our attention solution primarily supported elementary tasks similar to Griffin and Robinson (2015), but the *leader lines* and *color highlighting* solutions also should be evaluated for general map reading tasks, such as providing overview and summary context for narrative and exploratory visualization alike (Shneiderman 1996). Finally, we examined continuity (tested through genres) and attention in our study, holding all other tropes constant for experimental control. Future research opportunities exist to explore and empirically test the roles of mood, dosing, redundancy, metaphor, and voice to support visual storytelling with maps.

4. ***What is the influence of individual audience differences on their retention, comprehension, and reaction?*** Examining individual differences afforded insight into how dimensions of expertise, motivation, and prior beliefs influence retention, comprehension, and reaction. Familiarity with the internet and familiarity and interest with print versus online news sources most impacted retention. While familiarity and interest with online news sources remained influential on comprehension, prior beliefs that the topic is worthy of discussion also influenced comprehension. Notably, interaction effects regarding prior beliefs and comprehension were observed for the *US sea-level rise* theme only, suggesting that the visual storytelling theme *does* matter when considering individual differences. Whereas differences in genres and trope designs directly influenced retention and comprehension—with some variability by individual differences—individual differences, *not* the visual story design, appeared to have a greater overall influence on participant reaction to the visual stories. Familiarity with maps and information graphics, familiarity with the story theme, and prior beliefs that the story theme was worth discussing were among the influential individual differences on participant reaction.

Opportunities for future research on individual differences in visual storytelling (and cartography generally) are numerous. First, our use of Mechanical Turk, while successful in garnering wider demographic, geographic, and political diversity, limited our ability to assess the influence of individual differences on the tested visual story design considerations themselves (i.e., by theme, genres, or tropes). Future research is needed to replicate our results in a controlled setting with participants purposefully sampled by individual differences into comparable groups. Second, we evaluated just a small range of individual differences by expertise, motivation, and prior beliefs. Future research is needed to understand how individual differences and intersectional identities shape understandings from maps and visual stories (D'Ignazio and Klein 2020), with particular attention on how our reactions might change through time around critical events or across other lived experiences given the increased role maps play in new stories and data journalism. Relatedly, and following calls from Kosara and Mackinlay (2013) and Figueiras (2014), future research is needed to extend our initial treatment

of retention, comprehension, and reaction to fully embrace new measures of engagement, empathy, and emotion resulting from different visual story designs, as the real test of visual storytelling is its ability to help us make better, more informed decisions in how we treat ourselves, each other, and our world. Finally, self-reported, Likert-based measures are a relatively simple method of capturing information about individual differences—necessarily so for the purpose of this study—and alternative methods that more reliably screen for interest, familiarity, training, and prior beliefs are needed to fully explore the role of individual differences on the design of map-based visual stories. This limitation also relates to the potential issues related to the sampling imbalance between genre conditions noted above.

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REFERENCES

Allen, Mike, ed. 2017. *The SAGE Encyclopedia of Communication Research Methods*. Los Angeles: Sage Publications.

Anderson, Cary L., and Anthony C. Robinson. 2022. "Affective Congruence in Visualization Design: Influences on Reading Categorical Maps." *IEEE Transactions on Visualization and Computer Graphics* 28 (8): 2867–2878. **https://doi.org/10.1109/tvcg.2021.3050118**.

Andrienko, Natalia, Gennady Andrienko, and Peter Gatalsky. 2003. "Exploratory Spatio-temporal Visualization: An Analytical Review." *Journal of Visual Languages and Computing* 14: 503–541. **https://doi.org/10.1016/s1045-926x(03)00046-6**.

Bostock, Mike. 2014. "How To Scroll." **http://bost.ocks.org/mike/scroll**.

Brant, Rollin. 1990. "Assessing Proportionality in the Proportional Odds Model for Ordinal Logistic Regression." *Biometrics* 46 (4): 1171–1178. **https://doi.org/10.2307/2532457**.

Bushell, Sally. 2012. "The Slipperiness of Literary Maps: Critical Cartography and Literary Cartography." *Cartographica* 47 (3): 149–160. **https://doi.org/10.3138/carto.47.3.1202**.

Cairo, Alberto. 2017. *Nerd Journalism: How Data and Digital Technology Transformed News Graphics*. Barcelona: Universitat Oberta de Catalunya.

Caquard, Sébastien. 2011. "Cartographies of Fictional Worlds: Conclusive Remarks." *The Cartographic Journal* 48 (4): 224–225. **https://doi.org/10.1179/000870411X13203362557264**.

———. 2013. "Cartography I: Mapping Narrative Cartography." *Progress in Human Geography* 37 (1): 135–144. **https://doi.org/10.1177/0309132511423796**.

Caquard, Sébastien, and William Cartwright. 2014. "Narrative Cartography: From Mapping Stories to the Narrative of Maps and Mapping." *The Cartographic Journal* 51 (2): 101–106. **https://doi.org/10.1179/0008704114Z.000000000130**.

Caquard, Sébastien, and D. R. Fraser Taylor. 2009. "What is Cinematic Cartography?" *The Cartographic Journal* 46 (1): 5–8. **https://doi.org/10.1179/000870409X430951**.

Cartwright, William. 1999. "Extending the Map Metaphor using Web Delivered Multimedia." *International Journal of Geographical Information Science* 13 (4): 335–353. **https://doi.org/10.1080/136588199241238**.

Cattoor, Bieke, and Chris Perkins. 2014. "Re-Cartographies of Landscape: New Narratives in Architectural Atlases." *The Cartographic Journal* 51 (2): 166–178. **https://doi.org/10.1179/1743277413Y.0000000076**.

Caudle, Sharon L. 2004. "Qualitative Data Analysis." In *Handbook of Practical Program Evaluation, Second Edition*, edited by Joseph S. Whorley, Harry P. Hatry, and Kathryn E. Newcomer, 417–438. San Francisco: Wiley

Chapin, Mac, Zachary Lamb, and Bill Threlkeld. 2005. "Mapping Indigenous Lands." *Annual Review of Anthropology* 34: 619–638. **https://doi.org/10.1146/annurev.anthro.34.081804.120429**.

Cohen, Geoffrey L. 2012. "Identity, Belief, and Bias." In *Ideology, Psychology, and Law*, edited by Jon Hanson, 385–403. Oxford: Oxford University Press.

Cronon, William. 1992. "A Place for Stories: Nature, History, and Narrative." *The Journal of American History* 78 (4): 1347–1376. **https://doi.org/10.2307/2079346**.

D'Ignazio, Catherine, and Lauren Klein. 2020. *Data Feminism*. Boston: MIT Press.

Denil, Mark. 2017. "Storied Maps." *Cartographic Perspectives* 84: 5–22. **https://doi.org/10.14714/CP84.1374**.

Eccles, Ryan, Thomas Kapler, Robert Harper, and William Wright. 2008. "Stories in Geotime." *Information Visualization* 7 (1): 3–17. **https://doi.org/10.1057/palgrave.ivs.9500173**.

Elwood, Sarah. 2006. "Beyond Cooptation or Resistance: Urban Spatial Politics, Community Organizations, and GIS-Based Spatial Narratives." *Annals of the Association of American Geographers* 96 (2): 323–341. **https://doi.org/10.1111/j.1467-8306.2006.00480.x**.

Engebretsen, Martin, and Helen Kennedy. 2020. *Data Visualization in Society*. Amsterdam: Amsterdam University Press.

Figueiras, Ana. 2014. "How to Tell Stories Using Visualization." Paper read at 1*8th International Conference on Information Visualisation*. **https://doi.org/10.1109/IV.2014.78**.

Fish, Carolyn S. 2020a. "Cartographic Content Analysis of Compelling Climate Change Communication." *Cartography and Geographic Information Science* 47 (6): 492–507. **https://doi.org/10.1080/15230406.2020.1774421**.

———. 2020b. "Storytelling for Making Cartographic Design Decisions for Climate Change Communication in the United States." *Cartographica* 55 (2): 69–84. **https://doi.org/10.3138/cart-2019-0019**.

Gershon, Nahum, and Ward Page. 2001. "What Storytelling Can Do for Information Visualization." *Communications of the ACM* 44 (8): 31–37. **https://doi.org/10.1145/381641.381653**.

Gray, Jonathan, Lucy Chambers, and Liliana Bounegru. 2012. *The Data Journalism Handbook: How Journalists Can Use Data to Improve the News*: Sebastopol: O'Reilly Media.

Griffin, Amy L., and Julia McQuoid. 2012. "At the Intersection of Maps and Emotion: The Challenge of Spatially Representing Experience." *Kartographische Nachrichten* 62 (6): 291–299.

Griffin, Amy L., and Anthony C. Robinson. 2015. "Comparing Color and Leader Line Highlighting Strategies in Coordinated View Geovisualizations." *IEEE Transactions on Visualization and Computer Graphics* 21 (3): 339–349. **https://doi.org/10.1109/TVCG.2014.2371858**.

Griffin, Amy L., Travis White, Carolyn Fish, Beate Tomio, Haosheng Huang, Claudia Robbi Sluter, João Vitor Meza Bravo, Sara I. Fabrikant, Susanne Bleisch, Melissa Yamada, and Péricles Picanço. 2017. "Designing across Map Use Contexts: A Research Agenda." *International Journal of Cartography* 3 (sup1): 90–114. **https://doi.org/10.1080/23729333.2017.1315988**.

Haklay, Muki, Alex Singleton, and Chris Parker. 2008. "Web Mapping 2.0: The Neogeography of the GeoWeb." *Geography Compass* 2 (6): 2011–2039. **https://doi.org/10.1111/j.1749-8198.2008.00167.x**.

Haraway, Donna J. 1991. *Simians, Cyborgs, and Women: The Reinvention of Nature*: New York: Routledge.

Harley, J. B. 1989. "Deconstructing the Map." *Cartographica* 26 (2): 1–20. **https://doi.org/10.3138/E635-7827-1757-9T53**.

Harrower, Mark, and Benjamin Sheesley. 2005. "Designing Better Map Interfaces: A Framework for Panning and Zooming." *Transactions in GIS* 9 (2): 77–89. https://doi.org/10.1111/j.1467-9671.2005.00207.x.

Hauser, David, Gabrielle Paolacci, and Jesse Chandler. 2019. "Common concerns with MTurk as a participant pool: Evidence and solutions." In *Handbook of Research Methods in Consumer Psychology*, edited by Frank R. Kardes, Paul M. Herr, and Norbert Schwarz, 319–337. New York: Routledge. https://doi.org/10.4324/9781351137713-17.

Hullman, Jessica, Steven Drucker, Nathalie Henry Riche, Bongshin Lee, Danyel Fisher, and Eytan Adar. 2013. "A Deeper Understanding of Sequence in Narrative Visualization." *IEEE Transactions on Visualization and Computer Graphics* 19 (12): 2406–2415. https://doi.org/10.1109/TVCG.2013.119.

Joliveau, Thierry. 2009. "Connecting Real and Imaginary Places through Geospatial Technologies: Examples from Set-jetting and Art-oriented Tourism." *The Cartographic Journal* 46 (1): 36–45. https://doi.org/10.1179/000870409X415570.

Kent, Alexander. 2017. "Trust me, I'm a Cartographer: Post-truth and the Problem of Acritical Cartography." *The Cartographic Journal* 54 (3): 193–195. https://doi.org/10.1080/00087041.2017.1376489.

Koenitz, Hartmut, Gabriele Ferri, Mads Haahr, Diğdem Sezen, and Tonguç İbrahim Sezen. 2015. *Interactive Digital Narrative: History, Theory and Practice*. New York: Routledge.

Kosara, Robert, and Jock Mackinlay. 2013. "Storytelling: The Next Step for Visualization." *Computer* 46 (5): 44–50. https://doi.org/10.1109/MC.2013.36.

Lavery, Matthew Ryan, Parul Acharya, Stephen A. Sivo, and Lihua Xu. 2019. "Number of Predictors and Multicollinearity: What are their Effects on Error and Bias in Regression?" *Communications in Statistics-Simulation and Computation* 48 (1): 27–38. https://doi.org/10.1080/03610918.2017.1371750.

Lidwell, William, Kritina Holden, and Jill Butler. 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*. Beverly, MA: Rockport Pub.

Ma, Kwan-Liu, Isaac Liao, Jennifer Frazier, Helwig Hauser, and Helen-Nicole Kostis. 2012. "Scientific Storytelling Using Visualization." *IEEE Computer Graphics and Applications* 32 (1): 12–19. https://doi.org/10.1109/MCG.2012.24.

Macfarlane, Robert. 2007. *The Wild Places*. New York: Penguin.

McCullagh, Peter. 1980. "Regression Models for Ordinal Data." *Journal of the Royal Statistical Society: Series B (Methodological)* 42 (2): 109–127. https://doi.org/10.1111/j.2517-6161.1980.tb01109.x.

Miller, Christopher C. 2006. "A Beast in the Field: The Google Maps Mashup as GIS/2." *Cartographica* 41 (3): 187–199. https://doi.org/10.3138/J0L0-5301-2262-N779.

Monmonier, M. 1989. *Maps with the News: The Development of American Journalistic Cartography*. Chicago: University of Chicago Press.

———. 1992. "Authoring Graphic Scripts: Experiences and Principles." *Cartography and Geographic Information Systems* 19 (4): 247–260. https://doi.org/10.1559/152304092783721240.

Montello, Dan, and Paul Sutton. 2012. *An Introduction to Scientific Research Methods in Geography and Environmental Studies*. Thousand Oaks, CA: SAGE.

Moretti, Franco. 2005. *Graphs, Maps, Trees: Abstract Models for a Literary History*. London: Verso.

Muehlenhaus, Ian. 2014. "Looking at the Big Picture: Adapting Film Theory to Examine Map Form, Meaning, and Aesthetic." *Cartographic Perspectives* 77: 46–66. https://doi.org/10.14714/CP77.1239.

Nathans, Laura L., Frederick L. Oswald, and Kim Nimon. 2012. "Interpreting Multiple Linear Regression: A Guidebook of Variable Importance." *Practical Assessment, Research, and Evaluation* 17 (1): 9. https://doi.org/10.7275/5fex-b874.

Nielsen, Jacob. 2006. "F-shaped Pattern for Reading Web Content." *Nielsen Norman Group*. **https://www.nngroup.com/articles/f-shaped-pattern-reading-web-content-discovered**.

Ormeling, Ferjan. 1995. "New Forms, Concepts, and Structures for European National Atlases." *Cartographic Perspectives* 20: 12–20. **https://doi.org/10.14714/CP20.890**.

Pearce, Margaret Wickens, and Renee Pualani Louis. 2008. "Mapping Indigenous Depth of Place." *American Indian Culture and Research Journal* 32 (3): 107–126.

Pearce, Margaret Wickens. 2008. "Framing the Days: Place and Narrative in Cartography." *Cartography and Geographic Information Science* 35 (1): 17–32. **https://doi.org/10.1559/152304008783475661**.

———. 2009. "Place Codes: Narrative and Dialogical Strategies for Cartography." Paper read at *24th International Cartographic Conference*, November 15–21, Santiago, Chile.

———. 2014. "The Last Piece is You." *The Cartographic Journal* 51 (2): 107–122. **https://doi.org/10.1179/1743277414Y.0000000078**.

Phillips, Jonathan. 2012. "Storytelling in Earth Sciences: The Eight Basic Plots." *Earth-Science Reviews* 115 (3): 153–162. **https://doi.org/10.1016/j.earscirev.2012.09.005**.

Riche, Nathalie Henry, Christophe Hurter, Nicholas Diakopoulos, and Sheelagh Carpendale. 2018. *Data-Driven Storytelling*. Boca Raton: CRC Press.

Robinson, Anthony C. 2011. "Highlighting in Geovisualization." *Cartography and Geographic Information Science* 38 (4): 373–383. **https://doi.org/10.1559/15230406384373**.

Rogers, Simon. 2014. "Data Journalism is the New Punk." *British Journalism Review* 25 (2): 31–34. **https://doi.org/10.1177/0956474814538181**.

Rose, Gillian. 1997. "Situating Knowledges: Positionality, Reflexivities and Other Tactics." *Progress in Human Geography* 21 (3): 305–320. **https://doi.org/10.1191/030913297673302122**.

Roth, Robert E. 2009. "The Impact of User Expertise on Geographic Risk Assessment under Uncertain Conditions." *Cartography and Geographic Information Science* 36 (1): 29–43. **https://doi.org/10.1559/152304009787340160**.

———. 2013. "An Empirically-derived Taxonomy of Interaction Primitives for Interactive Cartography and Geovisualization." *IEEE Transactions on Visualization & Computer Graphics* 19 (12): 2356–2365. **https://doi.org/10.1109/TVCG.2013.130**.

———. 2021. Cartographic Design as Visual Storytelling: Synthesis and Review of Map-based Narratives, Genres, and Tropes. *The Cartographic Journal* 58 (1): 83–114. **https://doi.org/10.1080/00087041.2019.1633103**.

Roth, Robert E., and Mark Harrower. 2008. "Addressing Map Interface Usability: Learning from the Lakeshore Nature Preserve Interactive Map." *Cartographic Perspectives* 60: 46–66. **https://doi.org/10.14714/CP60.231**.

Segel, Edward, and Jeffrey Heer. 2010. "Narrative Visualization: Telling Stories with Data." *IEEE Transactions on Visualization and Computer Graphics* 16 (6): 1139–1148. **https://doi.org/10.1109/TVCG.2010.179**.

Shneiderman, Ben. 1996. "The Eyes Have It: A Task by Data Type Taxonomy for Information Visualization." Paper read at *IEEE Conference on Visual Languages*, at Boulder, CO.

Sieber, Renée E., Pamela J. Robinson, Peter A. Johnson, and Jon M. Corbett. 2016. "Doing Public Participation on the Geospatial Web." *Annals of the American Association of Geographers* 106 (5): 1030–1046. **https://doi.org/10.1080/24694452.2016.1191325**.

Smith, Jonathan M. 1996. "Geographical Rhetoric: Modes and Tropes of Appeal." *Annals of the Association of American Geographers* 86 (1): 1–20. **https://doi.org/10.1111/j.1467-8306.1996.tb01743.x**.

Stolper, Charles D., Bongshin Lee, Nathalie Henry Riche, and John Stasko. 2016. *Emerging and Recurring Data-driven Storytelling Techniques: Analysis of a Curated Collection of Recent Stories*. Redmond, WA: Microsoft. **https://www.microsoft.com/en-us/research/publication/emerging-and-recurring-data-driven-storytelling-techniques-analysis-of-a-curated-collection-of-recent-stories**.

Sui, Daniel, and Michael Goodchild. 2011. "The Convergence of GIS and Social Media: Challenges for GIScience." *International Journal of Geographical Information Science* 25 (11): 1737–1748. **https://doi.org/10.1080/13658816.2011.604636**.

Sweeney, M., M. Maguire, and B. Shackel. 1993. "Evaluating User-computer Interaction: A Framework." *International Journal of Man-Machine Studies* 38: 689–711. **https://doi.org/10.1006/imms.1993.1032**.

Thöny, Matthias, Raimund Schnürer, René Sieber, Lorenz Hurni, and Renato Pajarola. 2018. "Storytelling in Interactive 3D Geographic Visualization Systems." *ISPRS International Journal of Geo-Information* 7 (3): 123. **https://doi.org/10.3390/ijgi7030123**.

Vujaković, Peter. 2014. "The State as a 'Power Container': The Role of News Media Cartography in Contemporary Geopolitical Discourse." *The Cartographic Journal* 51 (1): 11–24. **https://doi.org/10.1179/1743277413Y.0000000043**.

Wallace, Timothy R. 2016. "Cartographic Journalism: Situating Modern News Mapping in a History of Map-User Interaction." PhD diss., University of Wisconsin–Madison.

Weber Reuschel, Anne-Kathrin, Barbara Piatti, and Lorenz Hurni. 2014. "Data-driven Expansion of Dense Regions–A Cartographic Approach in Literary Geography." *The Cartographic Journal* 51 (2): 123-140. **https://doi.org/10.1179/1743277414Y.0000000077**.

Weber, Wibke, and Hannes Rall. 2012. "Data Visualization in Online Journalism and its Implications for the Production Process." Paper read at *16th International Conference on Information Visualisation*. **https://doi.org/10.1109/IV.2012.65**.

Wieczorek, Anna Maria, Zuzanna Kłyszejko, Justyna Sarzyńska, Agnieszka Szóstek, Karolina Chmiel, Tomasz Soluch, and Aneta Brzezicka. 2014. "Mode of Text Presentation and its Influence on Reading Efficiency: Scrolling versus Pagination." *Studia Psychologica* 56 (4): 309–321.

Young, Mary Lynn, Alfred Hermida, and Johanna Fulda. 2018. "What Makes for Great Data Journalism? A Content Analysis of Data Journalism Awards Finalists 2012–2015." *Journalism Practice* 12 (1): 115–135. **https://doi.org/10.1080/17512786.2016.1270171**.

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PEER-REVIEWED ARTICLE

That's a Relief: Assessing Beauty, Realism, and Landform Clarity in Multilayer Terrain Maps

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Terrain maps are often composed of shaded relief along with other raster layers which we call thematic terrain layers to create aesthetically pleasing and clear maps of physical geography. Despite the fact that the interplay of layers is of primary concern to a cartographer, much of the research on terrain mapping has focused on studying terrain layers individually. This research aimed to fill this gap by evaluating the effect of combining shaded relief with thematic terrain layers and assessing ratings of beauty, realism, and landform clarity in an exploratory online user study. Specifically, we tested the combination of: manual, multidirectional, and ray-traced shaded relief with three thematic terrain layers: hypsometric tinting, land cover, and orthoimagery. There are five main findings from this exploratory study: (1) there was a direct correlation between beauty and realism scores, (2) the manual relief we tested was consistently rated lowest for beauty, realism, and landform clarity, and orthoimagery was rated the highest for beauty and realism, (3) shaded relief was more influential than thematic terrain layers on landform clarity ratings, (4) participant's geographic familiarity had a significant impact in four specific instances of the user study, and (5) neither shaded relief nor thematic terrain layers were the sole contributors to map reader perceptions of beauty, realism, or landform clarity. We conclude by identifying limitations in our stimuli design and presenting ideas for future research studies on terrain design.

KEYWORDS: aesthetics; terrain mapping; shaded relief; landform clarity; perception, beauty; realism; cartography; map design; hillshade

INTRODUCTION

Shaded relief, *relief shading*, and *hillshading* are terms often used interchangeably to refer to the cartographic technique of creating intuitive and realistic representations of topographic features on maps by mimicking the shadows cast by a light source. Shaded relief was initially created manually with an airbrush, pencil, or similar methods. However, modern digital processes have simplified the creation of beautiful, realistic, and clear relief for maps. We commonly access these tools in geographic information systems (GIS), but novel methods are increasing in popularity, some of which use 3D rendering software (Huffman 2017). Such tools allow cartographers to create shaded relief that more closely mimics the expressiveness and beauty of early manual shaded relief, but is more easily reproducible and time efficient to create.

The cartographer's chosen shaded relief method is not necessarily the sole contributor to a successful terrain map. Shaded relief is frequently combined with other raster layers, such as imagery or land cover, to create maps that offer the reader a clearer idea of the complexity of the landscape. The fact that these combinations are so popular suggests that an interaction between shaded relief and thematic terrain layers is often necessary to enhance the perceived beauty, realism, and clarity of the representation. Empirical research on relief shading has increased over the past decade, providing insight into new digital techniques to represent the topographic relief on maps (Jenny 2021; Jenny et al. 2020; Kennelly and Stewart 2014; Marston and Jenny 2015), user perception of illumination angles (Biland and Çöltekin 2017), and the perceived effectiveness of relief shading techniques (Farmakis-Serebryakova and Hurni 2020). However, few studies have investigated shaded relief combined with other thematic terrain layers (e.g. Çöltekin and Biland 2019; Huffman and Patterson 2013; Raposo and Brewer 2014). In these examples,

authors focused on one type of shaded relief and one type of thematic terrain layer, but to our knowledge, none of these studies specifically measured perceptions across combinations of different shaded relief designs and thematic terrain layers.

In this study, our goal was to better understand how the combination of shaded relief and thematic terrain layers affects map readers' perceptions of beauty, realism, and landform clarity. After examining two volumes of the North American Cartographic Information Society (NACIS) *Atlas of Design* (Steingisser, Rose, and Tierney 2018; Marston et al. 2020), along with award-winning maps from the NACIS Conference, we identified three shaded relief techniques that were commonly used: (1) manual shaded relief, (2) multidirectional shaded relief, and (3) ray-traced relief. In addition, cartographers often paired these types of shaded relief with other layers to portray the landscape more realistically. Across the selection of maps we viewed, many included (1) hypsometric tinting, (2) land cover, or (3) orthoimagery. After reviewing these maps, our study was guided by the following research question:

How do manual and analytical shaded relief techniques influence reader perceptions of *beauty*, *realism*, and *landform clarity* in terrain maps that incorporate hypsometric tinting, land cover, and orthoimagery?

Cartography is as much an art as it is a science (Cosgrove 2005). Thus, it makes sense to understand not only the effects of combining different layers to create terrain maps, but also how those combinations affect the perceived beauty, realism, and the clarity of landforms in a two-dimensional map.

The rest of the paper is organized as follows: in the next section we describe shaded relief and thematic terrain layers, then we describe the importance of aesthetics in cartography. We follow with a description of our methods for an exploratory online user study. In the fourth section we illustrate the results of our exploratory study and follow with a discussion of those results. In the final section of the paper, we conclude with an overview of our findings, some limitations, and future research ideas.

BACKGROUND

SHADED RELIEF

Shaded relief began as a hand-drawn art form that gave depth to a two-dimensional view from above by accurately representing landforms using localized light sources (Marston and Jenny 2015; Imhof 1982; Brassel 1974; Collier, Forrest, and Pearson 2003). Manual relief has its own individual styles, determined by the cartographer who designed the map. This means that these maps are difficult to reproduce since any two cartographers are likely to draw very different representations of the same location due to their personal style, skill level, and interpretation of the landscape. Manual techniques also allow a cartographer to adjust their representation to meet the needs of the particular landscape being shown. However, creating these maps manually is extremely time intensive, though generalization is a common way to reduce the time burden (Patterson 2018). Recently, there has been a reinvigorated interest in exploring manual techniques amongst contemporary practicing cartographers (e.g., Bell 2018), while cartographic researchers have also attempted to replicate the aesthetic quality of manual relief through algorithmic processes, allowing the style to be more available to digital mapmakers (Jenny et al. 2020).

With the onset of computers, digital, analytic methods overtook manually-created shaded relief due to the speed and consistency with which the cartographer could now create these types of terrain layers. Basic analytical relief shading can be created quickly in a GIS from a digital elevation model (DEM). Since this standard shaded relief algorithm uses a single light source, all landforms are treated equally, which sometimes results in (1) less explicit landscape depictions with a lack of structure in larger landforms (Marston and Jenny 2015), and (2) a lack of clarity for minor landforms, especially those within the shadowed slopes of larger landforms (Zakšek, Oštir, and Kokalj 2011). Adjusting the light angle to better capture most landforms in a relief map is one solution to this limitation (Biland and Çöltekin 2017). Multidirectional

shaded relief also provides a solution by casting multiple light sources from different sun angle directions (Loissios, Tzelepis, and Nakos 2007; Mark 1992; Tzelepis et al. 2020; Veronesi and Hurni 2014) and is now more easily accomplished in GIS.

Of growing interest to practicing cartographers, however, is the use of 3D rendering software to create shaded relief maps, specifically ray-tracing methods. Ray-tracing is a well-known computer graphics technique for 3D modeling and can simulate natural light to create photo-realistic digital images (Glassner 1989; Rademacher 1997). Similar to GIS methods for rendering relief, ray-tracing produces a 2D greyscale image given a light source direction. The major difference from typical GIS methods is that ray-tracing can render more complex optical effects and surface textures, which makes it a unique tool for depicting topographic relief. While an analytical hillshade algorithm determines a pixel's shading based solely on its orientation toward a light source, without accounting for any of the rest of the landscape, ray-tracing can model the light as it reflects, refracts, scatters, and diffuses off the adjacent surfaces (Huffman 2014; Morgan-Wall 2018; Stevens 2014). A handful of cartographers have openly shared tools, tutorials, and processes for generating relief using a 3D modeling program called Blender (**blender.org**), which utilizes ray-tracing algorithms (Huffman 2017; Powell 2016; Underwood 2019; Larson 2019; Atwood 2020). These materials have made this method for generating shaded relief more accessible and reproducible.

THEMATIC TERRAIN LAYERS

While shaded relief is often the key element in representing the physical landscape in terrain maps, it is just one layer. To create a more complete image of the terrain, shaded relief is typically paired with additional layers to provide context to the underlying landscape (Imhof 1982; Imus and Loftin 2012). Some of these layers can be derived from the elevation surface and augment the visualization of elevation change; Imhof (1982) refers to these layers as "abstractions," and they include hypsometric tinting, hachuring, and contour lines. In addition, layers such as land cover and orthoimagery can represent variation in vegetation and surface cover to add context and texture to the map.

In this exploratory research, we focus specifically on three layers which are commonly used in terrain mapping: hypsometric tinting, land cover, and orthoimagery (Figure 1). Hypsometric tinting is a method of representing elevation values using a continuous or classed single hue, multi-hue, or spectral color scheme (Figure 1, A). This, combined with shaded relief, reinforces elevation heights through color cues. However, using an evenly stretched scheme on world maps can cause a loss of lowland and highland detail, which can be remedied by creating locally enhanced hypsometric tinting (Huffman and Patterson 2013). In addition, the colors used may mislead a map reader if they do not mimic those of the underlying geography. Many authors suggest that the colors in elevation tinting should reflect hues one might see in the natural landscape (Imhof

Figure 1. (A) Hypsometric tint colorizing high elevations with a pale yellow color and lower elevations in darker pale green; (B) data from the National Land Cover Database with naturalistic colors applied to the land cover classes; (C) orthographic imagery (from Google) giving readers a realistic sense of the terrain.

1982; Patton and Crawford, 1977; Patterson and Jenny 2011). Land cover (Figure 1, B), in comparison, is a separate dataset which is often paired with shaded relief to create a naturalistic aesthetic (Patterson 2002). Land cover is typically stored as a raster dataset, in which each cell is assigned a singular land cover type (e.g., forest). Finally, orthographic imagery (Figure 1, C), such as geometrically corrected aerial photos or satellite images, can allow for instant recognition of place through the landforms, and the texture of the underlying topography (Peterson 2012; 2020). Supporting this claim, Hoarau and Christophe (2017) found that orthoimagery in maps adds realism and context, while other research has contradicted this by showing negative effects on map readers. For example, Çöltekin and Biland (2019) found that, when paired with shaded relief, orthoimagery can negatively affect landform perception.

AESTHETICS

The very nature of relief representation is rooted in artistic qualities and requires that careful thought be given to the aesthetic characteristics of a map (Imhof 1982). Cartographers frequently debate aesthetics, because of cartography's close ties to art and visual representation. As Kent et al. (2012, 14) state "opinions are strong and varied [regarding aesthetics] and there are no universal rules, even though when we say a map is 'beautiful' we believe others ought to agree with us." Regardless of the data conveyed and message being shared, the map must appeal in its representation (Field and Demaj 2012). While learning a set of rules and conventions for representing map features is conceivable, a cartographer's goal with a map is to not only be informationally effective but also aesthetically pleasing (Dent, Torguson, and Hodler 2008).

In the last decade, a handful of researchers have attempted to quantify the aesthetic response of map readers on several fronts. Limpisathian (2017) tested the visual contrast of maps at multiple scales and asked map readers to rank a series of color and contrast schemes based on their clarity and aesthetic qualities. Similarly, Fabrikant et al. (2012) tested a small group of map readers' arousal levels while reading several design iterations of the same map to investigate aesthetic preferences. Cartographers have also examined the micro-aesthetics in map typefaces (Guidero 2016). Contemporary cartographic researchers are answering a call to bring aesthetics to the center of cartographic theory and critique the factors that influence aesthetic decision making in cartography (Kent 2005).

The success of a terrain map is not dependent purely on how efficiently it conveys the information, but also on how it looks aesthetically. The function of the map and its graphical appearance are intertwined, and the visual effect of a map is constructed from the interplay of its elements (Kent et al. 2012). Creating an effective terrain map takes time, artistry, and aesthetic sensitivity (Imhof 1982). While mapmakers today have many digital tools to create shaded relief quickly and easily, many terrain cartographers refine, adjust, and perfect the relief in post-processing software (Patterson 1997; 2002; Tait 2002; Jenny and Patterson 2007; Imus and Loftin 2012). For example, by incorporating orthoimagery in terrain maps, the cartographer can achieve an appealing design aesthetic that adds complexity, texture, and realism to the representation (Raposo and Brewer 2014). Some researchers have conducted studies that test terrain maps to understand the design and aesthetic preferences (Raposo and Brewer 2014; Jenny et al. 2020). However, there is still minimal empirical research attempting to compare the aesthetic qualities between digital and manual shaded relief techniques.

METHODS

To answer the research question, we designed a within-subject user study to examine: (1) beauty, (2) realism, and (3) landform clarity across a set of maps with variations in shaded relief and thematic terrain layers.

PARTICIPANTS

We solicited 105 participants for the study from the recruitment site Prolific. Participants were able to participate if they were using a desktop computer and their Prolific profile indicated they were 18 years of age or older, a US resident, and fluent in English. Each participant was paid $4.97 USD through Prolific for approximately 15 minutes of their time after they completed the user study, and we approved their answers.

STIMULI

The stimuli for the user study consisted of nine different terrain maps of Crater Lake, Oregon, in the United States.

The maps were made up of a combination of three shaded relief layer designs and three thematic terrain layer designs (Figure 2).

The three relief layers we used were: (1) a manual shaded relief created by Bill von Allmen of the US National Park Service in 1988 and later edited by Tom Patterson, (2) a multidirectional shaded relief, and (3) a ray-traced shaded relief. We downloaded the manual relief map from the Shaded Relief Archive (**shadedreliefarchive.com/Crater-Lake.html**). The analytical relief layers (multidirectional and ray-traced) were derived from a 3.33-meter resolution DEM from a set of sample elevation models provided by Kennelly et al. (2021), and the bathymetry was derived from a 1-meter ASCII XYZ grid re-sampled to 3.33 meters (**pubs.usgs.gov/dds/dds-72/site/gridfaq.htm#getacopy**). The multidirectional shaded relief was created in QGIS (version 3.16.3) using the GDAL hillshade tool. The following parameters were set for the hillshade tool: vertical exaggeration (Z factor) was set to 3.0, the azimuth was set to 337.5 as suggested by Biland and Çöltekin (2017), the altitude was set to 45.0 degrees, with the multidirectional shading option. Our ray-traced relief map was created in Blender (version 2.82a). Using Blender for relief modeling requires the DEM to be converted to a 16-bit unsigned integer, which we did using a GDAL Warp command (Larson 2019). The parameters we used to create the ray-traced relief in Blender mimicked what is detailed in Huffman's tutorial (2017). The only deviating parameter we used was the surface displacement method, which we set to "Displacement and Bump." This option combines both the *displacement* option, allowing for larger amounts of displacement in the 3D model, and the *bump mapping* option, which preserves finer details and textures in the rendering. Combining the two methods can provide a good balance and reduce memory usage (Blender Documentation Team 2021).

The three thematic terrain layers we used were: (1) hypsometric tint, (2) land cover, and (3) orthographic imagery. The hypsometric tint layer was created from the same DEMs as the analytical shaded relief layers and used two separate color schemes, one for land surface elevations, using colors designed to mimic the vegetation and land cover of the region as suggested by Patterson and Jenny (2011), and a second color scheme for bathymetric depths. The land cover layer used raster data collected from the National Land Cover Database (NLCD), reclassified into three land cover types: (1) tree cover, (2) shrub/grass, and

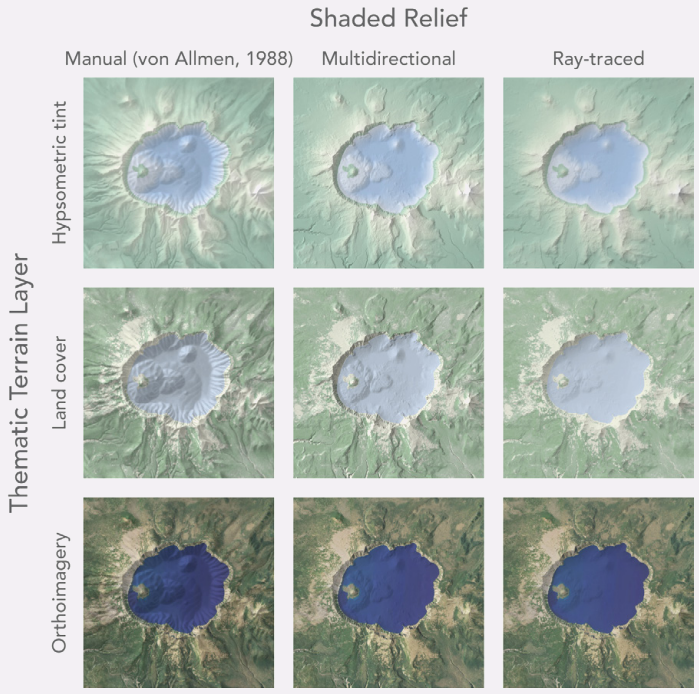


Figure 2. Nine variations of Crater Lake were created by overlaying three shaded relief maps (manual relief, multidirectional relief, and ray-traced relief) with three thematic terrain layers (hypsometric tint, land cover, orthoimagery).

(3) water. Finally, the orthographic image layer was derived from Google Maps. To avoid oversaturation and opposing shadows, we used the content-aware fill tool in Photoshop on areas of the orthoimage that appeared to be shaded so they did not conflict with the shaded relief's shadows.

There are two limitations of our stimuli design that we acknowledge could have had a confounding effect on the eventual results. First, von Allmen's manual relief depicted more generalized land and bathymetric relief and thus had less detail in the landforms depicted, compared to the multidirectional and ray-traced relief models. Second, we did not control for contrast, lightness, or saturation across the nine maps. We discuss the implications of these limitations more in the conclusion.

USER STUDY PROCEDURE

Participants found the study through the Prolific recruitment site. Once they clicked on the study, they were redirected to a Qualtrics site to take part in the user study. Participants were first asked to enter their Prolific ID and read through the consent form. Participants then continued to the four sections of the study: (1) a pre-test

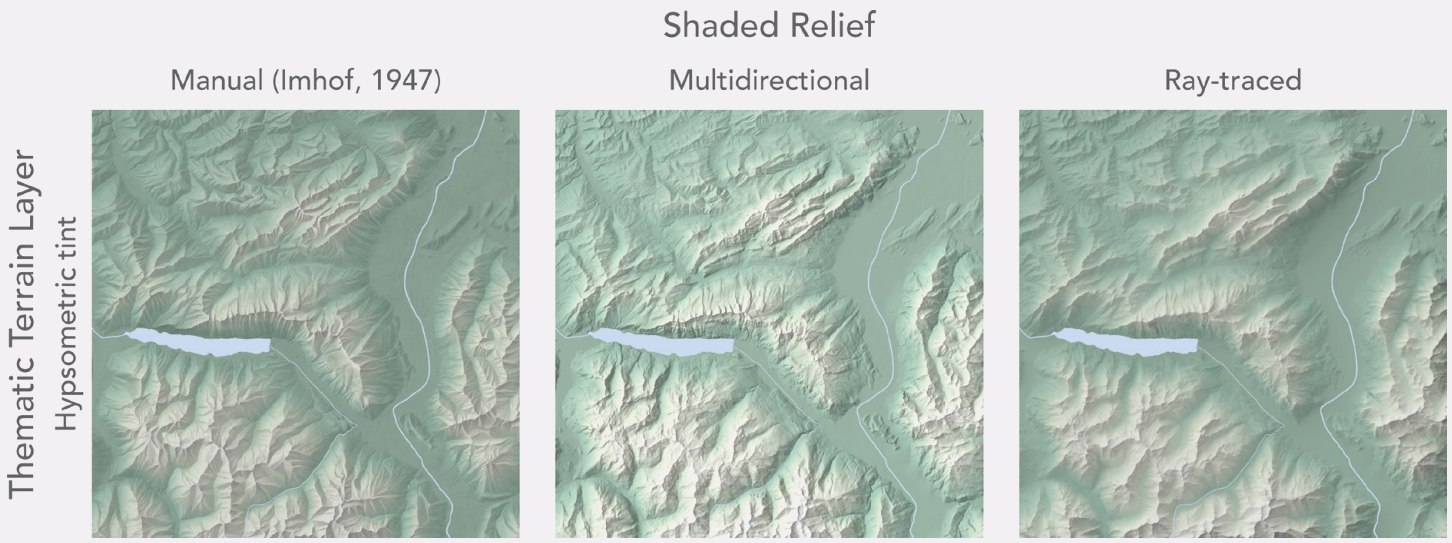


Figure 3. Three variations of Churfürsten, Switzerland were used to introduce participants to the rating tasks they would be completing later in the study. The manual shaded relief was created by Eduard Imhof in 1947 (shadedreliefarchive.com/NortheastSwitzerland.html).

questionnaire, (2) a tutorial, (3) the main user study, and (4) a final feedback question. The pre-test questionnaire consisted of six questions: two demographics questions on gender and education level, a question about their knowledge of cartography and map design, and three questions about their familiarity with the geographic focus of the study, Crater Lake, asking whether they had (1) heard of, (2) seen pictures or maps of, (3) or visited the area. Following the pre-test, participants navigated through a tutorial where they were introduced to the five rating tasks they would complete during the main user study. The tutorial used only three map designs and depicted a different geographic area, Churfürsten, Switzerland (Figure 3). This section introduced the term "terrain map," the purpose of relief shading in maps, and asked participants to rate the sample maps for their "beauty," "realism," and "landform clarity" (Figure 4).

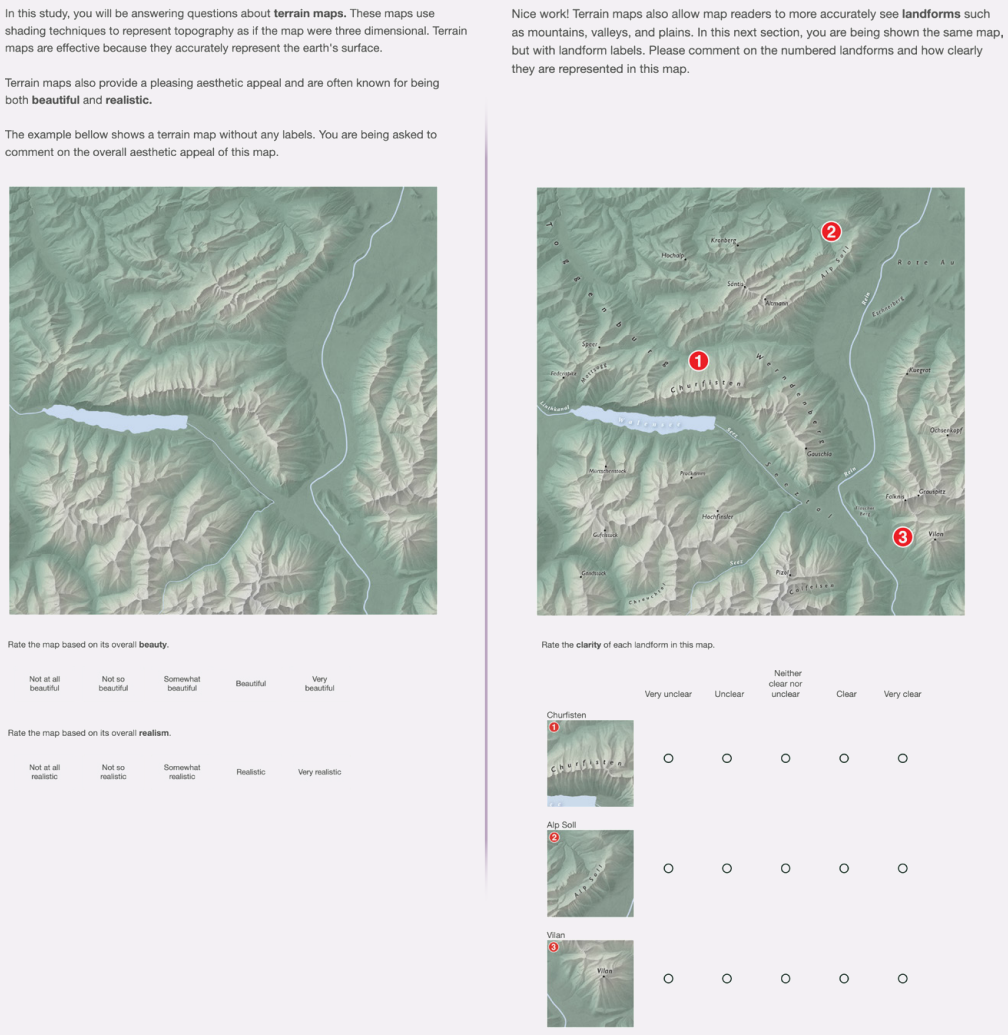
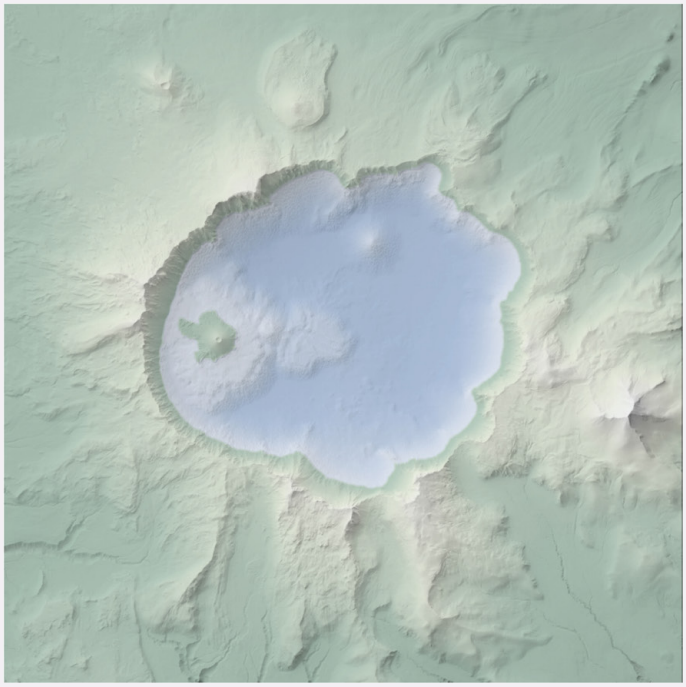


Figure 4. The tutorial section introduced the beauty, realism (left), and landform clarity (right) tasks to prime participants for the main portion of the user study.

Following the tutorial, participants started the main user study. In the main user study, the participants answered the same five questions they were introduced to in the tutorial, but for nine map designs, for a total of 45 questions. The five rating tasks per map design were divided across two web pages in Qualtrics. The first page included one of the nine stimuli maps and asked participants to rate its beauty and realism (Figure 5, left). The second page showed the same map with numbered annotations on the three landforms (Wizard Island, Mount Scott, and Grouse Hill) and asked participants to rate the clarity of those landforms (Figure 5, right). We selected these three

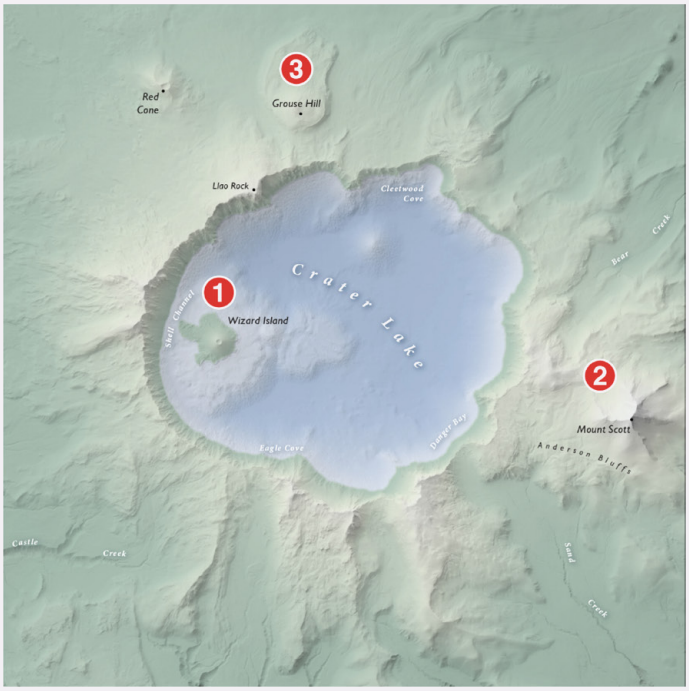


Rate the map based on its overall **beauty**.

Not at all beautiful	Not so beautiful	Somewhat beautiful	Beautiful	Very beautiful

Rate the map based on its overall **realism**.

Not at all realistic	Not so realistic	Somewhat realistic	Realistic	Very realistic



Rate the **clarity** of each landform in this map.

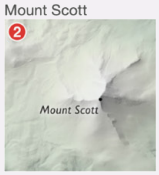
	Very unclear	Unclear	Neither clear nor unclear	Clear	Very clear
Wizard Island 	○	○	○	○	○
Mount Scott 	○	○	○	○	○
Grouse Hill 	○	○	○	○	○

Figure 5. Example from the study asking a user to rate the beauty, realism (left), and landform clarity (right) of the Crater Lake map design that blended a hypsometric tint and ray-traced relief.

landforms because they were similar in size and were located proximally to the main landform feature in the map (Crater Lake). Since the study was within-subjects, all participants saw all nine of the map designs. These were presented in random order for each participant to limit the possibility of a learning effect. Once participants finished the 45 rating tasks in the main user study, they were shown a final feedback question. The final feedback question of the user study asked participants to "Please provide any comments or feedback on your experience while taking part in this study," to gain qualitative insights on the stimuli design, user experience, and study design. Two attention-check questions were presented to participants during the study to ensure they were actively engaging in the survey. Once they finished all the questions, they were redirected back to Prolific and compensated for their time once we approved their answers.

ANALYSIS

First, we tested the data for normality using a Shapiro-Wilk test, and then we tested for equality of variance using a Levene's test. The results indicated that most of our data were not normally distributed and failed to demonstrate homogeneity of variance. Given this, non-parametric tests would be best suited for our data. However, there is some debate over to what degree the violation of these two assumptions affects statistical results (Scariano and Davenport 1987; Lix, Keselman, and Keselman 1996), and so we felt comfortable performing a parametric test: a two-way ANOVA with a Tukey HSD *post-hoc* test.

This ANOVA test was used to assess whether the choice of shaded relief and thematic terrain layers had a significant effect on beauty, realism, and landform clarity ratings. We chose a two-way ANOVA because in addition to independently testing the effect that shaded relief and thematic terrain layers had on rating scores, it also determines if there is a significant interaction effect between the two layers. This ability makes the two-way ANOVA a robust and valuable analysis for studies with two categorical independent variables (Norušis 2012). Essentially, an interaction occurs when "the effect of one independent variable is not the same for all levels of the other independent variable" (Rahman 2019, 125). However, since most of the samples failed the assumptions for a parametric analysis, we also ran a Welsh and Brown-Forsythe test to validate the ANOVA results. We then ran a Spearman's rank-order correlation to test the relationship between beauty and realism rating scores.

To assess if a participant's degree of familiarity with Crater Lake would have a confounding impact on the user study results, we ran two separate Independent Samples Mann-Whitney U tests for each of the three self-reported geographic familiarity questions. The first was for the combined mean rating scores of the participant's beauty, realism, and landform clarity task responses. The second was on the participant's independent rating scores for beauty, realism, and landform clarity tasks across the nine maps. For the samples that did pass the Shapiro-Wilk test or the Levene's test, we used an independent t-test to validate the results.

RESULTS

Of the initial 105 respondents, we removed ten responses because of incomplete answers, failed attention checks, or an indication that they had expert knowledge of cartographic design, leaving 95 total responses for analysis. Forty-eight of the participants indicated they identified as female, 46 identified as male, and one identified as non-binary. Most of our participants either had some college education (20%) or a 4-year degree (38%). When indicating their familiarity with Crater Lake, 64% had heard of it, 42% had seen photos or maps, and 11% had visited Crater Lake. Since our project was an exploratory examination of our research question, we did not formulate a hypothesis for the results. However, we did run a series of statistical analyses that would help us better understand the relationships between perceived beauty, realism, and landform clarity among our user study population.

BEAUTY AND REALISM RESULTS

Both beauty and realism had similar results from the two-way ANOVA. The beauty rating task showed a significant main effect for both shaded relief ($F(2,4) = 13.495$, $p < 0.001$), and thematic layer ($F(2,4) = 94.520$, $p < 0.001$), but we found no significant interaction between the two ($F(2,4) = 1.799$, $p = 0.115$) for the beauty rating scores. The thematic terrain layers had a larger effect size ($\eta^2 = 0.18$) on beauty rating scores than did shaded relief ($\eta^2 = 0.03$). Similarly, the realism rating task showed a significant main

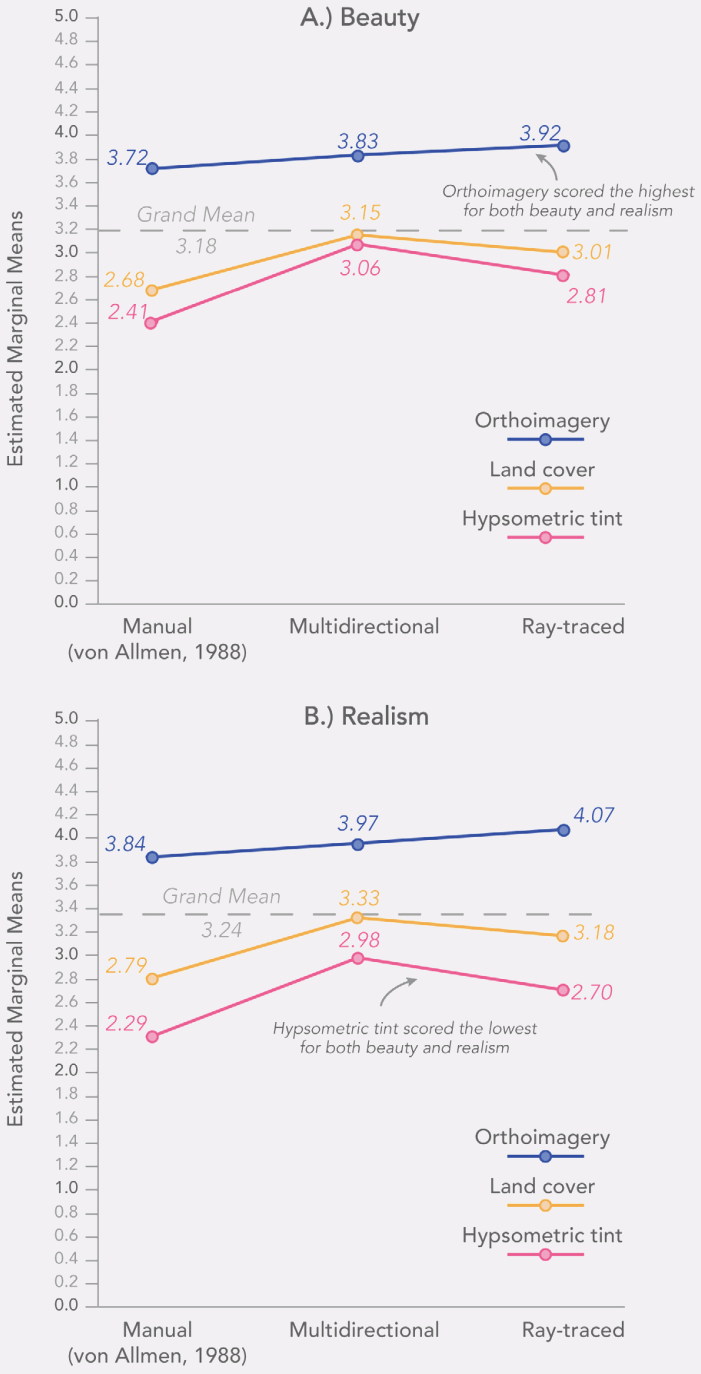


Figure 6. Estimated marginal means of beauty and realism scores from the two-way ANOVA. This graph shows the weighted means of beauty and realism scores for each thematic terrain layer averaged across the three shaded relief techniques. Greater distance between lines on the y-axis indicates a greater difference in rating scores for the combination of relief and thematic terrain layer.

effect for both shaded relief ($F(2,4) = 16.46$, $p < 0.001$) and thematic layer ($F(2,4) = 132.996$, $p < 0.001$) on realism rating scores, but no significant interaction between the two ($F(2,4) = 2.202$, $p = 0.067$). Thematic terrain layers

Figure 7. Pairwise comparison of beauty and realism results from the Tukey HSD *post-hoc* test.

also had a larger effect size ($\eta^2 = 0.24$) on realism rating scores than did shaded relief ($\eta^2 = 0.04$).

The Spearman's rank-order correlation showed a statistically significant relationship ($rs(8) = 0.653$, $p < 0.001$) and indicated there was a positive correlation between beauty and realism rating scores. Figure 6 shows the estimated marginal means plotted for beauty and realism. The estimated marginal means are the mean beauty and realism scores for each thematic terrain layer averaged across the three shaded relief techniques

The shaded relief Tukey HSD *post-hoc* test results were similar between the beauty and realism tasks. Results of the *post-hoc* tests revealed that beauty and realism scores for von Allmen's manual shaded relief were statistically significantly lower than both the ray-traced relief ($p = 0.001$ for beauty; $p < 0.001$ for realism) and multidirectional shaded relief ($p < 0.001$), and there was no significant difference between multidirectional shaded relief and ray-traced relief (Figure 7, A).

The Tukey HSD *post-hoc* test results for the thematic terrain layers differed slightly between the beauty and realism tasks. The tests revealed that beauty scores for orthoimagery were statistically significantly higher than both

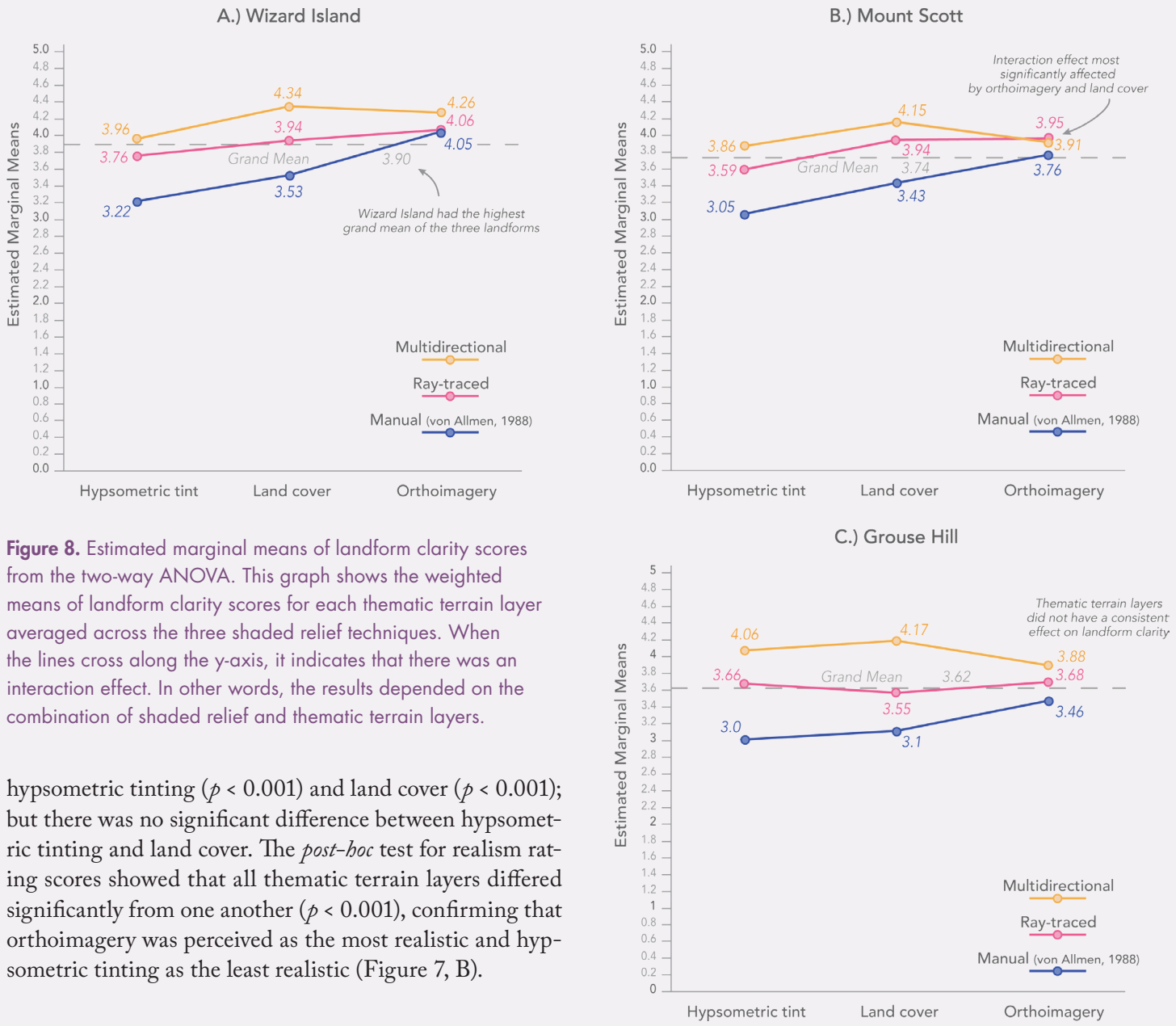


Figure 8. Estimated marginal means of landform clarity scores from the two-way ANOVA. This graph shows the weighted means of landform clarity scores for each thematic terrain layer averaged across the three shaded relief techniques. When the lines cross along the y-axis, it indicates that there was an interaction effect. In other words, the results depended on the combination of shaded relief and thematic terrain layers.

hypsometric tinting ($p < 0.001$) and land cover ($p < 0.001$); but there was no significant difference between hypsometric tinting and land cover. The *post-hoc* test for realism rating scores showed that all thematic terrain layers differed significantly from one another ($p < 0.001$), confirming that orthoimagery was perceived as the most realistic and hypsometric tinting as the least realistic (Figure 7, B).

LANDFORM CLARITY RESULTS

Across the three landforms (Wizard Island, Mount Scott, and Grouse Hill), results of the two-way ANOVA were not as consistent as the beauty and realism scores. For Wizard Island, the results of the two-way ANOVA showed a significant main effect for both shaded relief ($F(2,4) = 25.28$, $p < 0.001$), and thematic layer ($F(2,4) = 17.187$, $p < 0.001$), and a significant interaction between the two ($F(2,4) = 3.196$, $p = 0.013$) on clarity rating scores. Mount Scott also showed a significant main effect for both shaded relief ($F(2,4) = 21.76$, $p < 0.001$), and thematic layer ($F(2,4) = 10.86$, $p < 0.001$), and a significant interaction effect ($F(2,4) = 2.798$, $p = 0.025$). However, Grouse Hill only showed a significant main effect for shaded relief ($F(2,4) = 44.16$, $p < 0.001$) and a significant interaction effect ($F(2,4) = 2.798$, $p = 0.014$), but thematic terrain layers were not significant ($F(2,4) = 0.641$, $p = 0.527$). One similarity across the three landforms was that shaded relief had a larger effect size (Wizard Island: $\eta^2 = 0.056$; Mount Scott: $\eta^2 = 0.049$; Grouse Hill: $\eta^2 = 0.095$) on landform clarity scores than thematic terrain layers (Wizard Island: $\eta^2 = 0.039$; Mount Scott: $\eta^2 = 0.025$; Grouse Hill: $\eta^2 = 0.002$). Figure 8 shows the estimated marginal means of landform clarity scores plotted for each landform, which are the mean landform clarity scores for the shaded relief technique averaged across each thematic terrain layer.

The Tukey HSD *post-hoc* tests for shaded relief were similar for Wizard Island and Grouse Hill, but Mount Scott

Figure 9. Pairwise comparison of landform clarity for Wizard Island, Mount Scott, and Grouse Hill from the Tukey HSD *post-hoc* test.

had differences (Figure 9, A). The results showed all shaded relief methods were significantly different from one another ($p < 0.05$) for Wizard Island and Grouse Hill. However, for Mount Scott, von Allman's manual relief differed significantly from the other two shaded relief designs ($p < 0.001$); but multidirectional shaded relief and ray-traced relief were not significantly different from one another ($p = 0.213$).

For thematic terrain layers, the HSD *post-hoc* tests showed similar results between Wizard Island and Mount Scott, but not for Grouse Hill (Figure 9, B). Wizard Island and Mount Scott showed there was a significant difference between hypsometric tint and land cover (Wizard Island: $p = 0.001$; Mount Scott: $p < 0.001$); hypsometric tint and orthoimagery were significantly different ($p < 0.001$); but orthoimagery and land cover were not significantly different (Wizard Island: $p = 0.051$; Mount Scott: $p = 0.931$). Results for Grouse Hill indicated that thematic terrain layers were not a significant main effect, thus there was no significant difference between hypsometric tint, land cover, and orthoimagery.

Geographic Familiarity's Effect on Combined Rating Task Scores			
	1.) "Have you ever heard of. . .?"	*2.) "Have you ever seen photos or maps of. . .?"*	*3.) "Have you ever visited. . .?"*
Total N	95	95	95
Mann-Whitney U	1104.0	1141.5	356.5
Wilcoxon W	1699.0	2681.5	4011.5
Test Statistic	1104.0	1141.5	356.5
Standard Error	128.764	132.618	82.433
Standardized Test Statistic	0.520	0.313	-0.831
Asymptotic Sig. (2-sided test)	0.603	0.754	0.406

Table 1. No significant differences were found for the combined mean rating scores for beauty, realism, and landform clarity across the three geographic familiarity questions.

Significant Instances Where Geographic Familiarity Affected Individual Rating Tasks								
	1.) "Have you ever heard of. . .?"		*2.) "Have you ever seen photos or maps of. . .?"*				*3.) "Have you ever visited. . .?"*	
	Clarity: Wizard Is.		*Realism*		*Clarity: Wizard Is.*		*Clarity: Mt. Scott*	
	Multidirectional		*Multidirectional*		*Multidirectional*		*Manual*	
	Hypsometric Tint		*Hypsometric Tint*		*Land cover*		*Orthoimagery*	
	Yes	*No*	*Yes*	*No*	*Yes*	*No*	*Yes*	*No*
Total N	61	34	40	55	40	55	10	85
Mean Rank	42.98	57.00	56.44	41.86	64.90	46.01	64.90	46.01
Mann-Whitney U	1343.0		762.5		1386.0		256.0	
Wilcoxon W	1938.0		2302.5		2926.0		3911.0	
Test Statistic	1343.0		762.5		1386.0		256.0	
Standard Error	116.649		127.792		120.140		78.577	
Standardized Test Stat.	2.623		-2.641		2.381		-2.151	
Asymptotic Sig. (2-sided test)	0.009*		0.008*		0.017*		0.031*	

Table 2. Significance differences were found amongst four specific instances in the user study across the three geographic familiarity questions.

GEOGRAPHIC FAMILIARITY RESULTS

Geographic familiarity had no significant effect on participants' combined mean rating scores for beauty, realism, and clarity (Table 1). However, geographic familiarity had a statistically significant impact on four specific map designs between groups for each familiarity question (Table 2). Even though more participants had heard of Crater Lake (N = 61, M = 42.98), those who had not heard of Crater Lake (N = 32, M = 57) gave higher clarity ratings for Wizard Island when looking at the map design with multidirectional shaded relief and hypsometric tinting (U = 1343, p = 0.009). Participants who had seen photos or maps of Crater Lake (N = 40, M = 56.44) gave higher

realism ratings for the map using multidirectional shaded relief and hypsometric tinting (U = 762.5, p = 0.008) than those who had not seen maps or photos of Crater Lake (N = 55, M = 41.86). Those same participants who had seen photos or maps of Crater Lake (N = 40, M = 64.90) also gave higher clarity ratings for Wizard Island when looking at the map design using multidirectional shaded relief and land cover (U = 1386, p = 0.017) compared to those who had not seen maps or photos of Crater Lake (N = 55, M = 46.01). Of those who had visited Crater Lake (N = 10, M = 64.90) gave higher clarity ratings for Mount Scott when looking at the map design with von Allmen's manual shaded relief and orthoimagery (U = 256, p = 0.031) than those who had not visited.

DISCUSSION

BEAUTY AND REALISM RATING TASKS

Overall, there was a wide variety of responses to the beauty and realism rating tasks, and the ratings depended on the shaded relief and thematic terrain layers used. The ratings were influenced more by the thematic terrain layers than shaded relief designs in our stimuli, although they were both significant effects. And while both shaded relief and thematic terrain layers were significant, the scores were not dependent on the combination of thematic terrain and shaded relief, rather the two variables had unique outcomes on users' perceptions. Finally, the outcomes from both tasks showed there to be a correlation between perceived beauty and realism.

The effect of shaded relief on the beauty and realism ratings showed that participants consistently rated von Allmen's manual relief as the least beautiful and realistic of the three shaded relief methods. To some, this may be a surprising finding, because the cartographic community time and again has pointed to manual relief as the most artistic and realistic technique for representing terrain (Imhof 1982; Brassel 1974; Collier, Forrest, and Pearson 2003; Marston and Jenny 2015). However, this result confirmed our expectations, since manual relief inherently is tied to the cartographer's individual interpretation of the landscape through generalization (Patterson 2018). Our ray-traced relief and multidirectional shaded relief were both rated highly for perceived beauty and realism; however, even though multidirectional relief had a higher mean score compared to the ray-traced relief, the ratings were not significantly different between the two, so we cannot conclude if one was truly perceived as more beautiful or realistic.

For the thematic terrain layers, map readers found orthographic imagery to be the most beautiful and realistic. Orthographic imagery often adds more visual complexity than other thematic terrain layers, and tends to feature darker colors, making it a challenging layer to pair with overlaying vector data (Hoarau, Christophe, and Mustière 2013). It was surprising to see that orthoimagery was rated as the most beautiful, but this finding might suggest that visually complex images can be deemed aesthetically preferable. It was, however, not surprising that orthoimagery was the highest rated for the realism task, given the literature (Hoarau and Christophe 2017; Peterson 2012). This confirms Peterson's (2012) notion that incorporating satellite imagery into maps, such as with Google Maps, Google Earth, and other online navigation maps, provides context and an aesthetic that is more relatable to average map users. Further, common web map applications rarely use hypsometric tinting and land cover, which could have contributed to orthoimagery being rated higher in the beauty and realism rating tasks, since average map readers are more (and increasingly) familiar with imagery. Land cover and hypsometric tinting were both rated lower for perceived beauty and realism; however, for beauty ratings, the two thematic terrain layers were not significantly different, but for realism ratings, the results indicated that hypsometric tinting was perceived as the least realistic. This finding may have some merit, since hypsometric tinting is an abstraction of reality and, depending on the design, it is not always a realistic visualization of how the landscape looks. Depending on the location and the colors used in the representation, it has the potential to convey inaccurate information about vegetation, rainfall, or temperature (Patton and Crawford 1977). It was clear from these results that the combination of von Allmen's manual shaded relief and hypsometric tinting do not elicit a strong sense of realism, especially when compared to other depictions that use orthoimagery.

Our research found, regarding aesthetics, that more realistic images (maps with orthoimagery) were ranked higher

Figure 10. Heatmap showing the frequency of correlated beauty and realism responses for the entire user study. Participants frequently rated maps with the same Likert value for both beauty and realism. The graph shows a positive correlation between the two rating variables.

than abstract images (maps with land cover or hypsometric tinting). This is interesting because researchers who have studied the effects of naïve realism posit that photorealistic representations are strongly desired by participants, despite exhibiting lower performance scores in map interpretation as compared to abstract representations (Hegarty et al. 2009; Smallman and St. John 2005). Since our research did not have a series of map reading tasks, we cannot gauge if map interpretation is also negatively affected by more realistic representations. However, participants were clearly more drawn to orthoimagery for its aesthetic appeal. More research should be done to investigate the difference in map preference and performance as it is related to thematic terrain layers.

One of the most surprising findings was the direct correlation between beauty and realism scores. Cartographers have alluded to a connection between beauty and realism, claiming that a realistic cartographic representation of the landscape can aid in creating an appealing aesthetic quality for readers (Harvey 1980; Robinson 1989). In other words, the literature has suggested that a beautiful map is a realistic map. A Spearman's correlation statistic confirmed this relationship and showed that our map readers found the most/least beautiful maps were also the most/least realistic ones (Figure 10). Our research illustrates that beauty and realism are linked when shaded relief is combined with thematic terrain layers in terrain maps. Based on this research, it was clear that abstract representations like hypsometric tinting and von Allmen's manual relief were less preferable for beauty ratings, perhaps not because they are inherently unattractive, but because they were not as realistic and did not resemble the landscape as explicitly as did the orthoimagery and ray-traced relief used in our stimuli (Figure 11).

LANDFORM CLARITY RATING TASKS

The results of the user study showed that landform clarity ratings differed from beauty and realism ratings in certain ways but had some similarities as well. Much like the outcomes from the beauty and realism ratings, von Allmen's manual relief was rated lowest. Unlike the beauty and realism ratings, the landform clarity ratings showed that shaded relief was more influential on participant perceptions of landform clarity than thematic terrain layers. There was

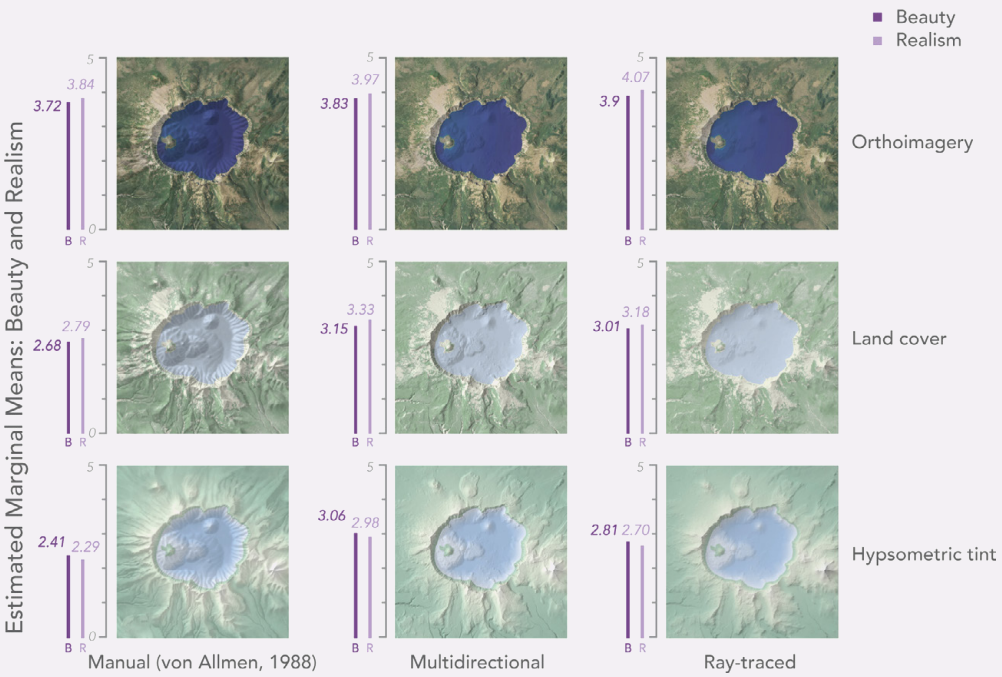


Figure 11. Comparison of estimated marginal means for beauty and realism rating scores by map. Scores were statistically similar between beauty and realism.

also a significant interaction effect between the shaded relief layers and the thematic layers for landform clarity ratings for all three landforms: Wizard Island, Mount Scott, and Grouse Hill, which we did not find for beauty and realism. This meant that there were unique outcomes for user perceptions of landform clarity depending on the pairing of shaded relief and thematic layers. This is an interesting finding because it suggests that specific pairings of shaded relief and thematic terrain layer types were more important for landform clarity than they were for beauty and realism in our study.

In terms of shaded relief on its own, depending on the landform in question, there was a different order of most to least clear shaded relief layer. Grouse Hill and Wizard Island both had the same, statistically significant order of perceived clarity: multidirectional shaded relief was the highest rated, ray-traced relief was second, and manual relief was the least clear. However, for Mount Scott, von Allmen's manual relief was the least clear, but there was no statistically significant difference between the two analytical shaded relief methods.

The effect of the thematic terrain layers on landform clarity ratings was also inconsistent across the three landforms, and not always a significant influencing factor. For example, the thematic terrain layers had an influence on clarity ratings for Wizard Island and Mount Scott, but not for Grouse Hill. This finding confirms that shaded relief had a stronger impact on each landform, since we statistically did not find that the thematic terrain layers played a significant role in influencing landform clarity on their own.

Testing the interaction of combining shaded relief and thematic terrain layers was statistically significant and provided insights into designing terrain maps with the goal of more clearly depicting landforms to map readers. In short, the differing combination of shaded relief and thematic layers led to different ratings of landform clarity, and this was dependent on the specific landform. For instance, with Mount Scott, landform clarity was highest when multidirectional relief was paired with land cover, but when multidirectional relief was paired with orthoimagery, the clarity was negatively affected. This was not the case for Grouse Hill and Wizard Island. For those two landforms, while the interaction effect was still significant, the pairing of the thematic terrain layers with multidirectional relief did not lead to such a dramatic effect on landform clarity. The interaction effect was interesting because shaded relief is rarely used in isolation, and it was clear that the thematic terrain layers had an effect depending on how they were paired with the shaded relief layers. This confirms that neither shaded relief nor thematic terrain layers are the sole contributor to a beautiful, realistic, or clear terrain map, but that the layers provide distinct qualities, and the interaction between shaded relief and thematic terrain is of importance for landform clarity, specifically.

Finally, the results of the landform clarity section of the user study experiment imply that figure-ground may be a confounding factor in landform clarity. For example, Wizard Island had the highest grand mean value for perceived clarity (M = 3.90), with Mount Scott following (M = 3.74), and Grouse Hill with the lowest (M = 3.62), suggesting that map readers on average found Wizard Island to be clearer than the other landforms. It is easy to see when looking at a map of Crater Lake, Oregon that, indeed, Wizard Island is a very prominent feature in the water-filled crater, followed by Mount Scott, the largest mountain landform in the vicinity, followed by Grouse Hill, which is far less visually prominent. It's understood that there is a special relationship between land and water regarding map interpretation (Head 1972) and that foreground features move up higher in the visual order (Haber and Hershenson 1973). This is especially true when foreground features have greater visual contrast (like the contrast between Wizard Island and the water of Crater Lake) which can help them stand out, become more distinguishable, and create a perceptually distinct sense of hierarchy (MacEachren and Mistrick 1992). The lower clarity scores for Grouse Hill, on the other hand, can be explained by these same theories. Indeed, one participant said that Grouse Hill "was [the] hardest to make clear" which was perhaps because of its lower elevation, minimal vertical height difference, and less contrast between the landform and the base of the hill. While the aim of this research was not to understand the connection between landform clarity and contrast, this result indicates that certain landforms might receive higher landform clarity ratings, regardless of their shaded relief and thematic terrain pairing, because of their figure-ground relationship.

GEOGRAPHIC FAMILIARITY

It is known that a person's landscape preference (Dearden 1984; Herzog et al. 2000) and map reading ability can depend on their prior level of geographic knowledge (Kaplan

1987). In this study, familiarity with Crater Lake, Oregon had a statistically significant impact in four specific instances in the user study. Participants who had never heard of Crater Lake were more likely to find Wizard Island to be most clear when multidirectional shaded relief and hypsometric tinting were combined. Interestingly, those who had seen photos and maps of Crater Lake rated Wizard Island as most clear when multidirectional shaded relief was combined with land cover instead. Those same participants were also more likely to rate the combination of multidirectional shaded relief and hypsometric tinting as most realistic. And finally, those who had visited Crater Lake were more likely to rate Mount Scott as most clear when von Allmen's manual relief was combined with orthoimagery.

CONCLUSION

Cartographers often combine shaded relief with thematic terrain layers when creating terrain maps, thus the primary aim of this research was to understand the relationship between these two layers on map reader perceptions of beauty, realism, and landform clarity. In an exploratory online user study, we tested the combination of three shaded relief layers (manual, multidirectional, and ray-traced) with three common thematic terrain layers (hypsometric tinting, land cover, and orthoimagery) in a series of maps of Crater Lake, Oregon and measured participants' ratings of beauty, realism, and landform clarity.

OVERVIEW OF THE FINDINGS

There were five main findings in this research, which we summarize here.

First, the results of this research showed there to be a direct correlation between beauty and realism scores, which were more influenced by thematic terrain layers than by shaded relief. Cartographers have long suggested a connection between beauty and realism, claiming that a realistic cartographic representation of the landscape can lead to a more appealing aesthetic (Harvey 1980; Robinson 1989), and our empirical research corroborated those claims. Given this, cartographers should keep in mind the link between these two aspects when designing terrain maps.

Second, we found von Allmen's manual relief to be consistently rated lowest for beauty, realism, and landform clarity, while orthoimagery was rated as most beautiful and realistic, and—when combined with certain shaded relief layers—sometimes improved landform clarity scores. These findings are surprising because, in general, professional cartographers hold manual relief in high regard. They promote it as a beautiful hand-drawn artform (Imhof 1982; Brassel 1974; Collier, Forrest, and Pearson 2003; Marston and Jenny 2015), while orthoimagery is often dismissed as being pedestrian and adding unnecessary visual complexity to maps (Hoarau, Christophe, and Mustière 2013; Touya, Hoarau, and Christophe 2016). This finding may suggest that cartographic experience affects a person's preferences, however, we cannot make any generalizing claims, given that we only tested novice map users and only used one example of hand-drawn shaded relief.

Third, in contrast to beauty and realism, the landform clarity ratings showed that shaded relief was more influential than the thematic terrain layers; however, there was a significant interaction effect, which meant that different landform clarity ratings arose from different combinations of layers. This is important because past research has focused largely on analyzing map reader perceptions of shaded relief on its own (Biland and Çöltekin 2017; Farmakis-Serebryakova and Hurni 2020; Jenny et al. 2020); however, this research makes it clear that every map has its own unique effect, based upon the combination of shaded relief and thematic terrain layers.

Fourth, a participant's familiarity with Crater Lake did not influence the overall combined rating scores for all nine maps, but only had a statistically significant impact in four specific instances in the user study. The findings suggest that different levels of familiarity influence reader perceptions depending on the question being asked and the specific combinations of shaded relief and thematic terrain layers.

Finally, in our study, neither shaded relief nor thematic terrain layers were the sole contributors to map readers' perceptions of beauty, realism, or landform clarity. Instead, these layers had distinct effects in different

situations depending on their pairing. This confirms that the interaction between shaded relief and thematic terrain layers is an important consideration when creating terrain maps.

LIMITATIONS AND FURTHER RESEARCH

Future research would be well served by building on the following limitations of this study:

1. While participants consistently rated von Allmen's manual relief as the least beautiful, realistic, and clear in depicting landforms, the particular drawing used in this study was just one example of this relief method. The look of a manual relief varies depending on the cartographer's style, skill level, and interpretation of the landscape. Additionally, both the land and bathymetric landforms in von Allmen's relief of Crater Lake were less detailed when compared to the digital relief models, which may have led to confounding effects on aesthetic perceptions between the different relief methods. Further research should verify these findings by testing multiple manual shaded relief drawings (Jenny et al. 2020), multiple geographies and landform types (Farmakis-Serebryakova and Hurni 2020), varying spatial scales, and different levels of detail.

2. This study did not consider contrast, lightness, or saturation, which may have had confounding effects on the results. The analysis showed that participants felt orthoimagery was the most realistic and beautiful; it was also the darkest, had the highest contrast, and the most saturated colors. One participant commented: "I noticed I liked the darker contrasted maps better than the lighter colored ones." Likewise, the maps that had the lowest ratings used hypsometric tinting, which was significantly lighter and less saturated. Other cartographic research has shown that map readers' preferences are strongly affected by contrast (Fabrikant et al. 2012; Limpisathian 2017; Brewer 1992). Future research should emphasize consistency in contrast, lightness, and saturation in terrain representation to avoid this potentially confounding variable.

3. In this research we only tested maps of one location. However, Raposo and Brewer (2014) found that map location and the types of landforms present in the stimuli played a significant role in readers' aesthetic preferences. Future research could involve showing participants maps of a variety of locations, such as in Jenny and Patterson (2021), manual relief from **shadedreliefarchive.com**, or using different landforms such as in Farmakis-Serebryakova and Hurni's (2020) experiment to either corroborate or challenge the findings of our exploratory research.

4. The results of this study also implied that the visual contrast of a landform may have been important in explaining why certain features were consistently rated higher for landform clarity than others. In this study, Wizard Island, arguably the most prominent feature in the Crater Lake area, was consistently rated as the most clearly distinguishable landform, while Grouse Hill was rated as the least clear. Since it is understood that land-water representation has a strong effect on map reader interpretation (Head 1972), there could be a correlation between Wizard Island's higher visual contrast and higher landform clarity ratings. Future research should control for or test the implications of contrast and figure-ground on ratings of beauty, realism, and landform clarity.

5. Participants noted, in the open-ended question, that seeing one map at a time lead to difficulty in judging the beauty and realism across all nine stimuli maps. Future experiments could involve allowing participants to see all or some of the map designs side-by-side when rating beauty and realism.

6. This research was conducted online and was limited to participants in the United States who did not have expert knowledge in cartographic design. Several potentially confounding variables should be controlled for or explored in future research. Perceptions of clarity and beauty might differ between participants using different screen sizes or digital devices; between participants given digital or paper maps; between participants in different parts of the world; and between novice participants and experts or practicing cartographers.

7. Participants were only asked to rate the beauty and realism of each map and comment on the clarity

of landforms. Future research could build upon our exploratory findings to also incorporate tasks that would require participants to interpret large and small landforms, engage in way-finding and navigation, or read overlaying vector information, all in order to investigate map reader performance (Castner and Wheate 1979; Hegarty et al. 2009; Raposo and Brewer 2014; Smallman and St. John 2005).

8. Finally, our research focused on just three shaded relief layers and three thematic terrain layers. Future researchers could expand on this by testing a wider range of layers or a range of parameters used to create these layers. Some examples of terrain map representation techniques to include in a future analysis are: texture shading (Brown 2014), neural network relief shading (Jenny et al. 2020), sky models (Kennelly and Stewart 2014), sky-view factor hillshading (Zakšek, Oštir, and Kokalj 2011), aerial perspective (Jenny and Patterson 2021), 2D versus 3D relief representations (Taveras 2018), plan oblique relief (Jenny and Patterson 2007), and Swiss-style color relief shading (Imhof 1982; Jenny and Hurni 2006).

CONCLUDING THOUGHTS

Maps are not just tools for navigating when we get lost, but also works of art worth getting lost in (Ribeiro and Caquard 2018; Harmon 2009). Perceived beauty and realism, in combination with assurance that map readers can accurately see specific landforms, is essential for producing a successful terrain map. With this in mind, our exploratory research provides cartographic researchers with a methodology for investigating aesthetics and landform clarity in terrain maps, with mindful consideration to both traditional and contemporary shaded relief methods when combined with thematic terrain layers. While the results of our research might imply some best practices, we cannot make any definitive claims that can be generalized outside of this study, due to the limitations discussed above. Given this, we encourage future researchers to build upon our work, and provide some helpful insight by further testing the combination of relief and thematic terrain layers.

REFERENCES

Atwood, Peter. 2020. "Relief Shading in Blender - Tips and Tricks with Peter Atwood." *Geospatial Frontier*. Accessed January 3, 2021. **https://www.geospatialfrontier.com/medialibrary/relief-shading-in-Blender-tips-and-tricks-with-peter-atwood**.

Bell, Sarah. 2018. "Drawing Hillshade: A Tutorial (with Time Lapse Videos)." *Petrichor*. Accessed January 3, 2021 **https://petrichor.studio/2018/10/22/drawing-hillshade-shaded-relief-with-time-lapse-video-demos**.

Biland, Julien, and Arzu Çöltekin. 2017. "An Empirical Assessment of the Impact of the Light Direction on the Relief Inversion Effect in Shaded Relief Maps: NNW is Better than NW." *Cartography and Geographic Information Science* 44 (4): 358–372. **https://doi.org/10.1080/15230406.2016.1185647**.

Blender Documentation Team. 2021. "The Blender 2.93 Manual." Accessed January 3, 2021. **https://docs.blender.org/manual**.

Brassel, Kurt. 1974. "A Model for Automatic Hill-shading." *The American Cartographer* 1 (1): 15–27. **https://doi.org/10.1559/152304074784107818**.

Brewer, Cynthia A. 1992. "Review of Colour Terms and Simultaneous Contrast Research for Cartography." *Cartographica* 29 (3–4): 20–30. **https://doi.org/10.3138/80ML-3K54-0204-6172**.

Brown, Leland. 2014. "Texture Shading: A New Technique for Depicting Terrain Relief." 9th ICA Mountain Cartography Workshop, April 22–26, 2014. **http://www.mountaincartography.org/activities/workshops/banff_canada/papers/brown.pdf**.

Castner, Henry W., and Roger Wheate. 1979. "Re-assessing the Role Played by Shaded Relief in Topographic Scale Maps." *The Cartographic Journal* 16 (2): 77–85. **https://doi.org/10.1179/caj.1979.16.2.77**.

Collier, Peter, David Forrest, and Alastair Pearson. 2003. "The Representation of Topographic Information on Maps: The Depiction of Relief." *The Cartographic Journal* 40 (1): 17–26. https://doi.org/10.1179/000870403235002033.

Çöltekin, Arzu, and Julien Biland. 2019. "Comparing the Terrain Reversal Effect in Satellite Images and in Shaded Relief Maps: an Examination of the Effects of Color and Texture on 3D Shape Perception from Shading." *International Journal of Digital Earth* 12 (4): 442–459. https://doi.org/10.1080/17538947.2018.1447030.

Cosgrove, Denis. 2005. "Maps, Mapping, Modernity: Art and Cartography in the Twentieth Century." *Imago Mundi* 57 (1): 35–54. https://doi.org/10.1080/0308569042000289824.

Dearden, Philip. 1984. "Factors Influencing Landscape Preferences: an Empirical Investigation." *Landscape Planning* 11 (4): 293–306. https://doi.org/10.1016/0304-3924(84)90026-1.

Dent, Borden, Jeff Torguson, and Thomas Hodler. 2008. *Cartography: Thematic Map Design, 6th Edition*. New York: McGraw-Hill.

Fabrikant, Sara I., Sidonie Christophe, Georgios Papastefanou, and Sara Lanini-Maggi. 2012. "Emotional Response to Map Design Aesthetics." GIScience 2012: Seventh International Conference on Geographic Information Science, Columbus, OH, 18 September 18–21, 2012. https://doi.org/10.5167/uzh-71701.

Farmakis-Serebryakova, Marianna, and Lorenz Hurni. 2020. "Comparison of Relief Shading Techniques Applied to Landforms." *ISPRS International Journal of Geo-Information* 9 (4): 253. https://doi.org/10.3390/ijgi9040253.

Field, Kenneth, and Damien Demaj. 2012. "Reasserting Design Relevance in Cartography: Some Concepts." *The Cartographic Journal* 49 (1): 70–76. https://doi.org/10.1179/0008704112Z.00000000011.

Glassner, Andrew S., ed. 1989. *An Introduction to Ray Tracing*. San Francisco: Morgan Kaufmann.

Guidero, Elaine Meredith. 2016. "Where Cartography Meets Typography: Choosing Typefaces and Semantic Effects for Maps Using Microaesthetics." PhD diss., The Pennsylvania State University.

Haber, Ralph N., and Maurice Hershenson. 1973. *The Psychology of Visual Perception*. New York: Holt, Rinehart & Winston.

Harmon, Katharine. 2009. *The Map as Art: Contemporary Artists Explore Cartography*. New York: Princeton Architectural Press.

Harvey, Paul Dean Adshead. 1980. *The History of Topographical Maps: Symbols, Pictures and Surveys*. London: Thames and Hudson.

Head, C. Grant. 1972. "Land-water Differentiation in Black and White Cartography." *Cartographica* 9 (1): 25–38. https://doi.org/10.3138/L486-X2R8-6821-14P7.

Hegarty, Mary, Harvey S. Smallman, Andrew T. Stull, and Matt S. Canham. 2009. "Naïve Cartography: How Intuitions about Display Configuration Can Hurt Performance." *Cartographica* 44 (3): 171–186. https://doi.org/10.3138/carto.44.3.171.

Herzog, Thomas R., Eugene J. Herbert, Rachel Kaplan, and C. L. Crooks. 2000. "Cultural and Developmental Comparisons of Landscape Perceptions and Preferences." *Environment and Behavior* 32 (3): 323–346. https://doi.org/10.1177/0013916500323002.

Hoarau, Charlotte, and Sidonie Christophe. 2017. "Cartographic Continuum Rendering Based on Color and Texture Interpolation to Enhance Photo-Realism Perception." *ISPRS Journal of Photogrammetry and Remote Sensing* 127: 27–38. https://doi.org/10.1016/j.isprsjprs.2016.09.012.

Hoarau, Charlotte, Sidonie Christophe, and Sébastien Mustière. 2013. "Mixing, Blending, Merging or Scrambling Topographic Maps and Orthoimagery in Geovisualization?" 26th International Cartographic Conference, Dresden, Germany. https://www.researchgate.net/publication/255979488_Mixing_blending_merging_or_scrambling_topographic_maps_and_orthoimagery_in_geovisualizations.

Huffman, Daniel P. 2014. "Shaded Relief in Blender." 9th ICA Mountain Cartography Workshop, April 22–26, 2014. http://www.mountaincartography.org/activities/workshops/banff_canada/papers/huffman.pdf.

———. 2017. "Creating Shaded Relief in Blender." *somethingaboutmaps*. Accessed January 1, 2021. https://somethingaboutmaps.wordpress.com/2017/11/16/creating-shaded-relief-in-blender.

Huffman, Daniel P., and Tom Patterson. 2013. "The Design of Gray Earth: A Monochrome Terrain Dataset of the World." *Cartographic Perspectives* 74: 61–70. https://doi.org/10.14714/CP74.580.

Imhof, Eduard. 1982. *Cartographic Relief Presentation*. Berlin: Walter de Gruyter. https://doi.org/10.1515/9783110844016.

Imus, David, and Paula Loftin. 2012. "The Beauty of Clear Communication." *Cartographic Perspectives* 73: 103–106. https://doi.org/10.14714/CP73.591.

Jenny, Bernhard, and Lorenz Hurni. 2006. "Swiss-Style Colour Relief Shading Modulated by Elevation and by Exposure to Illumination." *The Cartographic Journal* 43 (3): 198–207. https://doi.org/10.1179/000870406X158164.

Jenny, Bernhard, Magnus Heitzler, Dilpreet Singh, Marianna Farmakis-Serebryakova, Jeffery Chieh Liu, and Lorenz Hurni. 2020. "Cartographic Relief Shading with Neural Networks." *IEEE Transactions on Visualization and Computer Graphics* 27 (2): 1225–1235. https://doi.org/10.1109/TVCG.2020.3030456.

Jenny, Bernhard. 2021. "Terrain Generalization with Line Integral Convolution." *Cartography and Geographic Information Science* 48 (1): 78–92. https://doi.org/10.1080/15230406.2020.1833762.

Jenny, Bernhard, and Tom Patterson. 2007. "Introducing Plan Oblique Relief." *Cartographic Perspectives* 57: 21–40. https://doi.org/10.14714/CP57.279.

———. 2021. "Aerial Perspective for Shaded Relief." *Cartography and Geographic Information Science* 48 (1): 21–28. https://doi.org/10.1080/15230406.2020.1813052.

Kaplan, Stephen. 1987. "Aesthetics, Affect, and Cognition: Environmental Preference from an Evolutionary Perspective" *Environment and Behavior* 19 (1): 3–32. https://doi.org/10.1177/0013916587191001.

Kennelly, Patrick J., and A. James Stewart. 2014. "General Sky Models for Illuminating Terrains." *International Journal of Geographical Information Science* 28 (2): 383–406. https://doi.org/10.1080/13658816.2013.848985.

Kennelly, Patrick J., Tom Patterson, Bernhard Jenny, Daniel P. Huffman, Brooke E. Marston, Sarah Bell, and Alexander M. Tait. 2021. "Elevation models for reproducible evaluation of terrain representation." *Cartography and Geographic Information Science* 48 (1): 63–77. https://doi.org/10.1080/15230406.2020.1830856.

Kent, Alexander J. 2005. "Aesthetics: a Lost Cause in Cartographic Theory?" *The Cartographic Journal* 42 (2): 182–188. https://doi.org/10.1179/000870405X61487

Kent, Alexander J., Kenneth Field, Bernhard Jenny, and Anja Hopfstock. 2012. "Cartographic Design and Aesthetics 'FAQ'." *Cartographic Perspectives* 73: 13–16. https://doi.org/10.14714/CP73.594.

Larson, Joe. 2019. "Yet Another Blender Hillshade Tutorial." *Joe's Page*. Accessed January 3, 2021. https://joelarson.com/2019/04/07/Blender-hillshades.html.

Limpisathian, Pongpichaya. 2017. "Evaluating Visual Contrast and Hierarchy Relations of Cartographic Features Across Multi-Scale Map Displays." Master's thesis, The Pennsylvania State University.

Lix, Lisa M., Joanne C. Keselman, and Harvey J. Keselman. 1996. "Consequences of Assumption Violations Revisited: A Quantitative Review of Alternatives to the One-Way Analysis of Variance F Test." *Review of Educational Research* 66 (4): 579–619. https://doi.org/10.3102/00346543066004579.

Loissios, Dimitrios, Nikolaos Tzelepis, and Byron Nakos. 2007. "A Methodology for Creating Analytical Hill-shading by Combining Different Lighting Directions." 23rd International Cartographic Conference, August 4–10, 2007. http://www.mountaincartography.org/publications/papers/ica_cmc_sessions/5_Moscow_Session_Mountain_Carto/moscow_loisios.pdf.

MacEachren, Alan M., and T. A. Mistrick. 1992. "The Role of Brightness Differences in Figure-ground: is Darker Figure?" *The Cartographic Journal* 29 (2): 91–100. https://doi.org/10.1179/caj.1992.29.2.91.

Mark, Robert K. 1992. *A Multidirectional, Oblique-weighted, Shaded-relief image of the Island of Hawaii*. No. 92-422. US Geological Survey. https://doi.org/10.3133/ofr92422.

Marston, Brooke E., and Bernhard Jenny. 2015. "Improving the Representation of Major Landforms in Analytical Relief Shading." *International Journal of Geographical Information Science* 29 (7): 1144–1165. https://doi.org/10.1080/13658816.2015.1009911.

Marston, Brooke, Caroline Rose, Nat Case, and Vanessa Knoppke-Wetzel, eds. 2020. *Atlas of Design, Volume Five*. Milwaukee, WI: North American Cartographic Society.

Morgan-Wall, Tyler. 2018. "Throwing Shade at the Cartographer Illuminati: Raytracing the Washington Monument in R." *Rayverse Blog*. Accessed January 20, 2022. https://www.tylermw.com/throwing-shade.

Norušis, Marija J. 2012. *IBM SPSS Statistics 19 Statistical Procedures Companion*. Upper Saddle River, NJ: Prentice Hall.

Patterson, Tom. 1997. "A Desktop Approach to Shaded Relief Production." *Cartographic Perspectives* 28: 38–39. https://doi.org/10.14714/CP28.694.

———. 2002. "Getting Real: Reflecting on the New Look of National Park Service Maps." *Cartographic Perspectives* 43: 43–56. https://doi.org/10.14714/CP43.536.

———. 2018. "Relief Presentation on US National Park Service Maps." *Proceedings of the ICA* 1: 1–5. https://doi.org/10.5194/ica-proc-1-90-2018.

Patterson, Tom, and Bernhard Jenny. 2011. "The Development and Rationale of Cross-blended Hypsometric Tints." *Cartographic Perspectives* 69: 31–46. https://doi.org/10.14714/CP69.20.

Patton, Jeffrey C., and Paul V. Crawford. 1977. "The Perception of Hypsometric Colours." *The Cartographic Journal* 14 (2): 115–127. https://doi.org/10.1179/caj.1977.14.2.115.

Peterson, Gretchen N. 2012. *Cartographer's Toolkit: Colors, Typography, Patterns*. Fort Collins, CO: PetersonGIS.

Peterson, Gretchen N. 2020. *GIS Cartography: A Guide to Effective Map Design*. Boca Raton, FL: CRC Press. https://doi.org/10.1201/9781003046325.

Powell, Owen. 2016. "Owen Powell - Maps and Terrain Models." *BlenderNation*. Accessed January 3, 2021. https://www.Blendernation.com/2016/09/03/owen-powell-maps-terrain-models.

Rademacher, Paul. 1997. "Ray Tracing: Graphics for the Masses." *XRDS: Crossroads, The ACM Magazine for Students* 3 (4): 3–7. https://doi.org/10.1145/270955.270962.

Rahman, Akm Samsur. 2019. "Effects of Nanofibers on Properties of Geopolymer Composites." In *Nanotechnology in Eco-efficient Construction*, edited by Fernando Pacheco-Torgal, Maria Vittoria Diamanti, Ali Nazari, Claes Goran Granqvist, Alina Pruna, and Serji Amirkhanian, 123–140. Cambridge: Woodhead Publishing. https://doi.org/10.1016/B978-0-08-102641-0.00006-2.

Raposo, Paulo, and Cynthia A. Brewer. 2014. "Landscape Preference and Map Readability in Design Evaluation of Topographic Maps with an Orthoimage Background." *The Cartographic Journal* 51 (1): 25–37. https://doi.org/10.1179/1743277412Y.0000000027.

Ribeiro, Daniel Melo, and Sébastien Caquard. 2018. "Cartography and Art." *The Geographic Information Science & Technology Body of Knowledge*. https://doi.org/10.22224/gistbok/2018.1.4.

Robinson, Arthur. 1989. "Cartography as an Art." *Cartography Past, Present, and Future: A Festschrift for F. J. Ormeling*, edited by D. W. Rhind and D. R. F. Taylor, 91–102. https://doi.org/10.1016/B978-1-85166-336-1.50013-8.

Scariano, Stephen M., and James M. Davenport. 1987. "The Effects of Violations of Independence Assumptions in the One-Way ANOVA." *The American Statistician* 41 (2): 123–129. **https://doi.org/10.1080/00031305.1987.10475459**.

Smallman, Harvey S., and Mark St. John. 2005. "Naïve Realism: Misplaced Faith in Realistic Displays." *Ergonomics in Design* 13 (3): 6–13. **https://doi.org/10.1177/106480460501300303**.

Steingisser, Alethea, Caroline Rose, and Lauren Tierney, eds. 2018. *Atlas of Design, Volume Four*. Milwaukee, WI: North American Cartographic Society.

Stevens, Joshua. 2014. "HDRI Lighting for Shaded Relief Maps." *Joshuastevens.net*. Accessed January 20, 2022. **https://www.joshuastevens.net/cartography/hdri-lighting-for-shaded-relief-maps**.

Tait, Alex. 2002. "Photoshop 6 Tutorial: How to Create Basic Colored Shaded Relief" *Cartographic Perspectives* 42: 12–17. **https://doi.org/10.14714/CP42.550**.

Taveras, Aaron M. 2018. *The Performance of 2D and 3D Tsunami Evacuation Maps: A Case Study for Seaside, Oregon*. Master's thesis, Humboldt State University.

Touya, Guillaume, Charlotte Hoarau, and Sidonie Christophe. 2016. "Clutter and Map Legibility in Automated Cartography: A Research Agenda" *Cartographica* 51 (4): 198–207. **https://doi.org/10.3138/cart.51.4.3132**.

Tzelepis, Nikolaos, Alexandra Kaliakouda, Vassilios Krassanakis, Loukas-Moysis Misthos, and Byron Nakos. 2020. "Evaluating the Perceived Visual Complexity of Multidirectional Hill-shading." *Geodesy and Cartography* 69 (2): 161–172. **https://doi.org/10.24425/gac.2020.131085**.

Underwood, Nick. 2019. "Beyond Hillshading in Blender - Breaking Cartographic Convention with Care" North American Cartographic Information Society Annual Meeting, October 15–18, 2019. **https://www.youtube.com/watch?v=VUyR8GQYuU8**.

Veronesi, Fabio, and Lorenz Hurni. 2014. "Changing the Light Azimuth in Shaded Relief Representation by Clustering Aspect." *The Cartographic Journal* 51 (4): 291–300. **https://doi.org/10.1179/1743277414Y.0000000100**.

Zakšek, Klemen, Kristof Oštir, and Žiga Kokalj. 2011. "Sky-View Factor as a Relief Visualization Technique." *Remote Sensing* 3 (2): 398–415. **https://doi.org/10.3390/rs3020398**.

DOI: 10.14714/CP100.1753

PEER-REVIEWED ARTICLE

A Stylistic Study of the Hand-Painted Winter Panorama Maps of Pierre Novat

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I present a study of the hand-painted winter panoramas of Atelier Novat, a workshop founded by Pierre Novat (1928–2007) in the 1960s, whose style was perpetuated by his children Arthur and Frédérique. I offer a portrait of Pierre Novat and a brief historical overview of the workshop. The contribution of the paper is to describe the style of Novat through the analysis of its constituent elements: creation process, color palette, terrain deformation, light effects, and surface texture (trees, rocks, roads, and buildings). Creating an ideal yet personal representation of a mountain has a dual purpose: a practical one, to help the viewer understand the topography of the region, and an aesthetic one, to depict an imaginary mountain, now iconic of the French Alps, that encourages dreams. The paper concludes with a review of existing methods, in cartography and computer graphics, for the creation of digital panoramas.

KEYWORDS: panorama maps; landscape visualization; hand-painting; ski maps; French Alps; Pierre Novat

Figure 1. *Grand Massif,* Pierre Novat, 1986. The most accomplished painting of his career according to his son, Arthur Novat.

1. INTRODUCTION

In this paper, I am interested in characterizing the style of the French panoramist Pierre Novat (1928–2007). I will review the main aspects of his style, from the shades used in his paintings, to the depiction of lighting effects and surface texture, including the deformation of the terrain.

CONTEXT

Atelier Novat is a workshop founded in the 1960s by the French panoramist Pierre Novat. Through the subsequent years, the atelier (workshop) achieved national fame, delivering over 300 panoramas in total. Novat's panoramic maps accompanied the boom of alpine skiing in France in the latter half of the twentieth century, becoming emblematic of this period and helping to promote ski resorts. Figure 1 displays a 1986 panorama of Grand Massif (108 cm × 74 cm), representative of Novat's work. He has had a lasting impact on how the mountain landscapes are represented and perceived in the French collective imagination.

A fundamental problem among panorama makers is the transmission of their expertise from one generation to the next, as very few masters are capable of creating these pieces of work. A great loss of expertise occurred with the death of Pierre Novat in 2007, eight years after the death of the most famous panoramist, Heinrich C. Berann (1915–1999).

Novat's children, Arthur and Frédérique carried on the work of their father, but never trained apprentices. Frédérique Novat is now retired and Arthur Novat is about to cease his activity. That would mark the end of Atelier Novat. After them, who will know how to create panoramic maps in the style of Pierre Novat? In an attempt to save this knowledge, several multidisciplinary initiatives were launched, e.g., the MECOMO project (Balzarini, Dalmasso, and Murat 2015; Balzarini and Murat 2016), in which Arthur Novat was involved, but considerable work remains to be done.

METHODOLOGY

I am a researcher from the expressive (i.e., non-photorealistic) rendering branch of the computer graphics community. My long term goal is to provide artists with the means to convey information clearly through images, while maintaining a rich variety of available styles. The creation of panoramas is a prime case study in that regard.

It is in this context that I established a close collaboration with Arthur Novat. Through my careful observation of his painting, I have acquired a solid knowledge of the Novat style. To support this work, I also conducted several interviews with Arthur Novat in 2020 and 2021, and another with him and his sister, Frédérique Novat, in 2021. I also attended painting workshops taught by Arthur Novat. All my claims in this paper have been validated with Arthur Novat. Conversely, no claims made by the Novats that I could not verify myself in the panoramas were included.

PREVIOUS WORKS

Though they achieve different styles in the end, panorama artists who have become prominent masters in the field all share a similar creative process. Several authors have previously examined the processes of panoramists, or have conducted interviews with them to document their methods.

Patterson (2000) provided an in-depth study of the work of Heinrich C. Berann, the most famous panoramist. Patterson (2000) and Kast and Fischer (2019) have interviewed Berann's former apprentice, Heinz Vielkind, about their methods. Tait studied James Niehues's maps, which are "in use at over a quarter of all ski areas" in North America (2010, 5). Weyland (2004), Kelly (2021), and Preppernau (2022; see elsewhere in this issue) have interviewed Niehues, while Bennett, Farrow, and Blevins (2019) described his technique in their book *The Man Behind the Maps*. A compilation of Pierre Novat's paintings and details about his creative process can be found in *Plans des Pistes* (Novat, Novat, and Belluard 2013). Finally, Dauer (2020) brings together the work of leading panoramists depicting the Alps.

In the next section, I will briefly introduce the concept of panoramas. In Section 3, I present the origins of Atelier Novat and its history, underlining elements that may have impacted the style of Pierre Novat. Then, I will describe his process for creating a panorama (Section 4). In Section 5, I examine what I think makes Novat's work so recognizable: the shades of blue he uses. Section 6 identifies and describes the main constituent elements of his style

regarding terrain deformation and lighting phenomena. I address the role of surface texture elements (trees, rocks, roads, and buildings) in Section 7. Finally, I review the relevant research works that enable the creation of digital panoramas in the style of traditional artists in Section 8.

2. ON PANORAMAS

The word panorama (from Ancient Greek *pan* "all" and *horama* "view") was coined by Robert Barker (1739–1806) to describe a way to display 360° paintings. He applied for a British patent in 1787 and has since been credited with the invention of panoramas (Oettermann 1997; Patterson 2000). Barker's painting of Edinburgh (1788) was displayed in a rotunda, a circular building in which viewers were surrounded by the painting, fully immersing them in the scene (Figure 2). The word panorama was used to designate both the paintings and the buildings used to display them.

Nowadays, the definition of panorama has evolved, and is neither limited to 360° paintings nor to the technical way of displaying such paintings. A panorama refers to a wide-angle view of a scene (e.g., a landscape or historical battle), regardless of the medium. Digital photographs as well as paintings can be called panoramas.

According to Tom Patterson, "panoramas are a unique variety of map that transcends the boundary between cartography and art . . . and are excellent pictorial devices for visualizing landscapes—especially ski areas, for which the panorama has become the de facto cartographic standard" (Patterson 2000, 39). As maps, they help the viewer understand the topography of the region, placing the ski areas in a wider geographic context. As paintings, they represent the personal interpretation of the artist, mixing reality with an imaginary representation of the landscape. The overall goal of these panoramas is to entice skiers to explore all the areas of a resort, luring them with ideal weather conditions, a deep snowpack, and downhill pistes (ski runs). They serve a practical purpose. These two

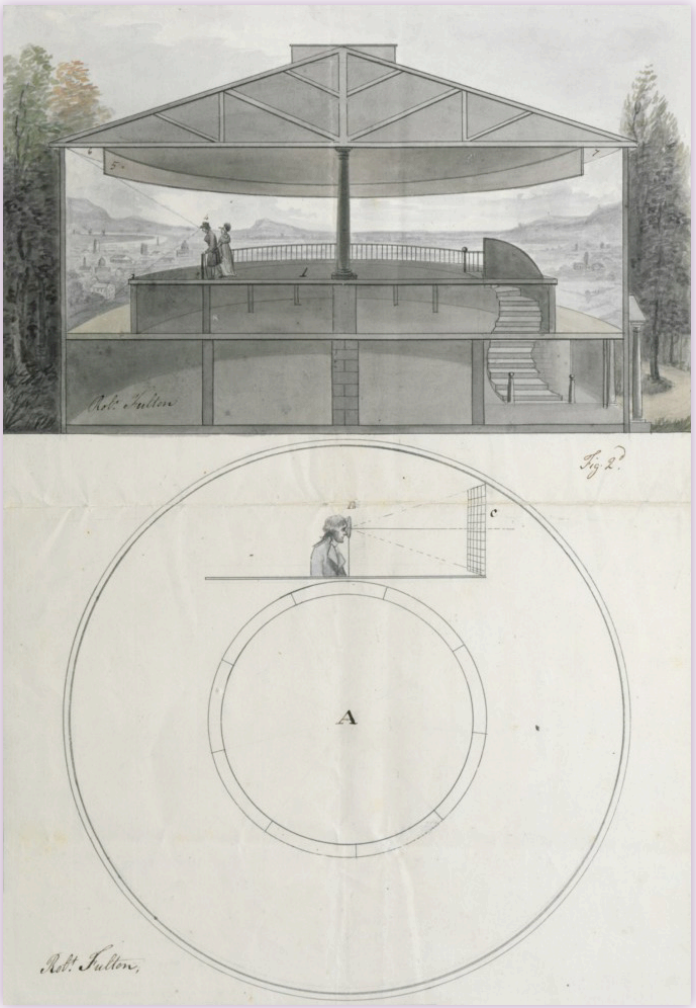


Figure 2. Illustration of the concept of "Panorama" in a French patent by Robert Fulton (1799).

modes imply that panoramists are themselves at the crossroads between the fine arts and the applied arts. Pierre Novat was no exception, and considered himself more of an artisan than an artist.

In France, similar to North America (Tait 2010), panoramas are the standard for mountain resorts. They are widely used by mountain operators to promote their resorts, and have played an important role in the development of winter sport tourism.

3. ABOUT PIERRE NOVAT

Pierre Novat (see Figure 3 for a photograph) attended the École Nationale Supérieure des Beaux-Arts (National School of Fine Arts) in Lyon. There, he enrolled in the decorative arts track, not the painting one. After finishing his studies, he yielded to his love for the mountains and moved to Val d'Isère (in the French Alps) in 1956, at

the age of 28. There he created an open workshop, simply named "L'Atelier" ("The Workshop"), in which he sold drawings, painted decorative items, some of which were made from enameled glass, and was open to the commissions of walk-in clients for bigger decorative works such as shop signs and murals. He built a whole network in Val d'Isère and quickly achieved local fame as Novat "the painter."

In the early 1960s, he moved back to Lyon for family reasons. Still, he received his first painting commission, to update the panorama of the Val d'Isère ski resort, which had originally been painted by Berann. As the resort was evolving quickly with the creation of ski tracks in Tignes (a neighboring village of Val d'Isère), the panorama by Berann had become outdated. Berann, being already quite famous at the time and busy with his commissions for the National Geographic Society, declined to make the necessary changes. Novat was therefore asked to paint the missing part. To obtain a pleasing result, he had to emulate the style of Berann and stitch his part to the existing panorama seamlessly (see Figure 4). But he did not yet envision that painting panoramas would become his main activity.

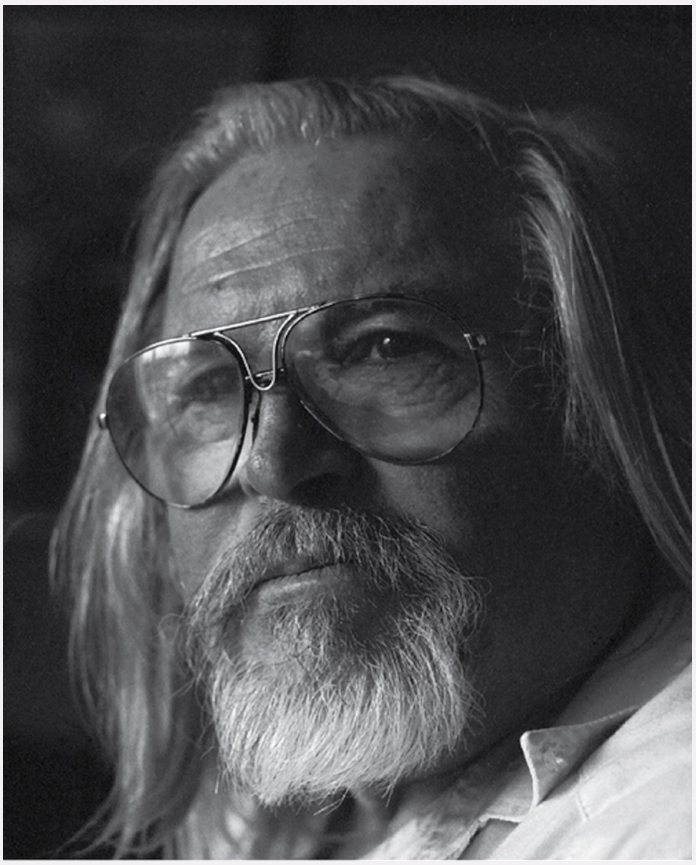


Figure 3. Portrait of Pierre Novat, circa 1995.

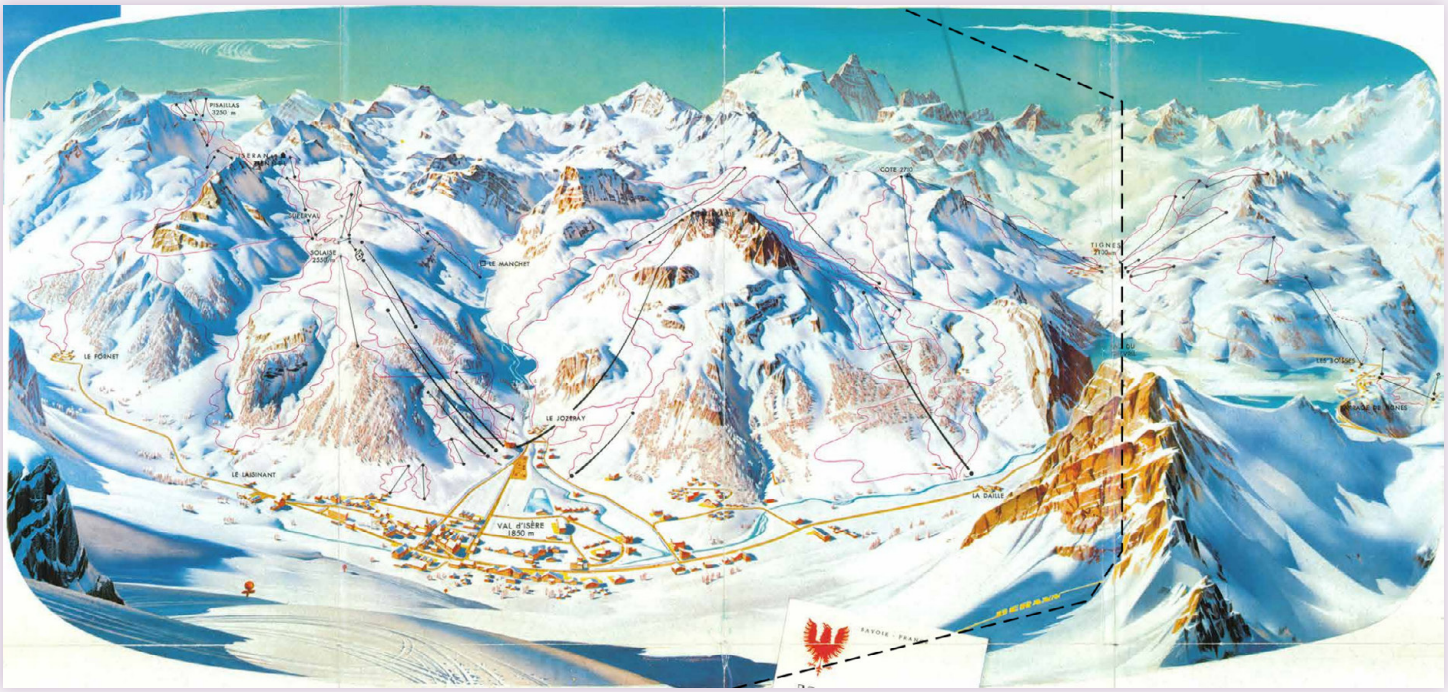


Figure 4. Left of the dashed line is the original panorama map for the Val d'Isère ski resort by Heinrich Berann. Right of the dashed line is the part added by Pierre Novat in 1962 to display Tignes and its surroundings. Novat also made some alterations to the left part directly on the original to support the creation of new tracks leading to Le Fornet. Novat's children still have the left panel but knowing exactly what is from Novat's hand proves difficult, if not impossible. This resort is now well-known as Espace Killy. See Figure 5 for the 1984 version of the panorama.

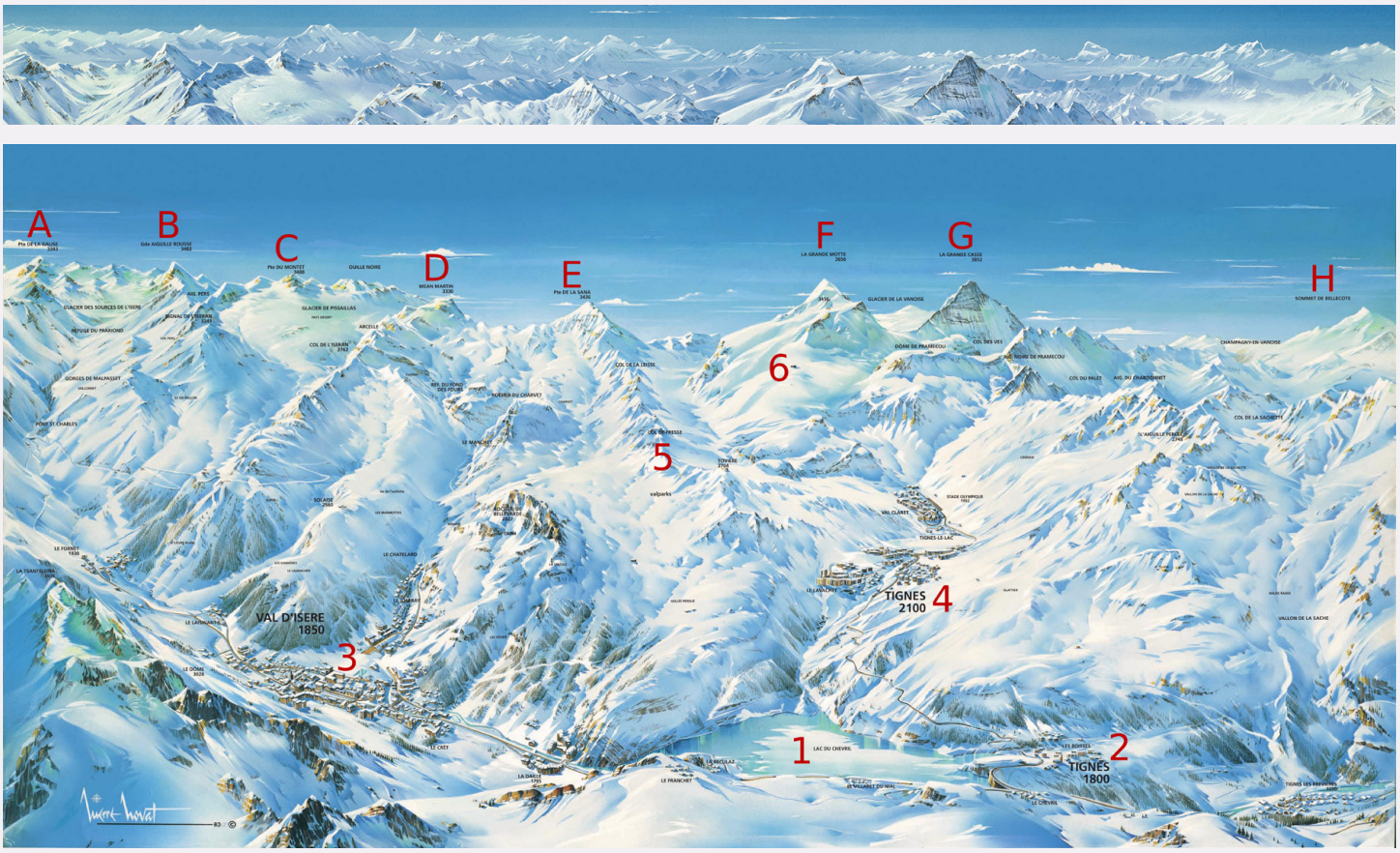


Figure 5. Top: Background portion of Pierre Novat's 1983 panorama of Espace Killy. Bottom: 1984 version of the panorama, one of the most emblematic by Novat. Note how the focus has moved with respect to the 1962 version (Figure 4). Chevril Lake (1) is now at the center and Val d'Isère (3) on the left. The labeled landmarks (A–H, 1–6) are referred to later in the article and in Figure 10.

The head of the Courchevel resort (called Saint-Bon at the time) contacted him in 1964 to paint his first complete panorama. For the next decade, he painted about one panorama every three years. By 1975, it became a full-time occupation, with a panorama painted every six months. He finally abandoned his professional identity of decorator—until then all panoramas were signed "Pierre Novat décorateur"—but he never fancied himself as an artist.

Novat painted more than 300 panoramas over the course of his career. His artworks were widely used as promotional materials such as piste maps, site plans, and brochures. Their aesthetic quality made them the preferred marketing tool for resorts, while also being better at depicting relief than 2D maps for skiers. The art of Pierre Novat accompanied the rise of modern alpine skiing in the 1970s and the 1980s and durably impacted the representation of the French Alps and Pyrénées in the collective imagination.

4. DESIGNING AND PAINTING A PANORAMA

Since the 1960s, Atelier Novat has produced most of the French mountain panoramas. This painstaking work was done by hand, first by Pierre Novat alone, then with, and finally by, his children Arthur and Frédérique.

COMMISSIONED ARTWORKS

Panoramas are most of the time commissioned by corporate ski resorts, which introduces an economic dimension that influenced the work of Pierre Novat. That is why the topographical reality sometimes gives way to a so-called economic reality. Clients would sometimes ask Novat to hide the valley of a competing resort, to exaggerate the size of the ski areas, to represent on the same map two diametrically opposed valleys (e.g., Val d'Isère and Tignes, Figure 5), etc. They have highly specific requests not only because of their own mental representations of the mountain and their vision of what the panorama should depict,

but also because of their artistic tastes and even for practical reasons (the safety of skiers, accessibility of the trails to snow groomers, location of the lifts, etc.). An example is the deletion of the background on the panorama of Espace Killy between the 1983 and 1984 versions (Figure 5). The goal was to focus attention on the resort itself, rather than depicting it as part of the broader alpine landscape. The whole panorama was also re-colored after the client asked for warmer tones.

Remaining faithful to the topography while meeting the client's requirements leaves little room for the artist to express their creativity. Their degrees of freedom mainly reside in the colors chosen, and in areas of the panorama that are of lesser importance to the client. When moving away from the main focus of the panorama, the resort, we can feel these constraints loosening. For instance, see background and sides of Figures 1 and 5 (top) that are less precise, but vivid nonetheless.

Even though these economic and geographic constraints partly governed Novat's work, he did develop a unique style that is now iconic of the French Alps in people's minds, and is still praised for the beauty of his landscapes as well as the precision and readability of the maps.

CRAFTING THE PANORAMA

Novat, Novat, and Belluard (2013) describe Pierre Novat's creation process. It starts with a careful observation of a topographic map on which a main viewpoint is chosen. Then, aerial photographs are taken by the painter or sent by the ski resort. Nowadays, in addition to maps, Arthur also uses satellite imagery. These photographs are stitched together to create a panoramic view of the scene. Then, a grayscale sketch is drawn (see Figure 6) on tracing paper sheets, with all the lighting effects already present. Some parts of the sketch are then cut out so that they can be repositioned freely, but they are rarely redrawn. All parts are adjusted into a final view that already includes all terrain details and surface texture elements (trees, rocks, roads, and buildings, see Section 7).

At this stage, Novat would often say that the panorama was already finished and that adding colors to it was a mere formality. Before working on the final painting, the pencil drawing is shown to the client. After approval, masks are created to protect some areas from the airbrush spraying (Novat's favorite tool) and to preserve sharp contours for shadows. Finally, after having traced the main elements of the penciled panorama on the canvas with colored pencils, paint is applied directly onto the canvas. The entire process takes anywhere from a few weeks to four months to complete, depending on the depicted region, the constraints of the commission, and the available workforce.

Despite the similarities in their creative processes, and despite the many constraints imposed by the clients, panoramists still achieve different styles. In the next sections I will focus on the characteristic style of Novat.

Figure 6. Left: Close-up of a pencil sketch made for *Espace Killy* 1983 (Figure 9, c). Right: The same area of the resulting panorama converted to grayscale. The sketch already depicts the finest details of the terrain, shading, shadowing, and surface texture.

5. ON THE SHADES OF BLUE

What usually strikes viewers at first sight in the winter panoramas of Atelier Novat is the dominance of blue. Regardless of the color palette, a blue ash gouache (Linel number 52, not produced anymore) is always used as a base and mixed across the panorama in numerous shades. *Grand Massif* and *Espace Killy* (Figures 1 and 5, respectively) demonstrate this clearly.

In Figure 7, I extracted color palettes from several panoramas using a median-cut algorithm (Heckbert 1982). Each displays 25 colors, where each color is the average of an equal number of pixels in the panorama, therefore it contains the 25 most representative colors of a panorama. It clearly illustrates the dominance of blue in Novat's work, a key characteristic that makes his panoramas instantly recognizable from others. Other panoramists, though having their own styles, do not rely as much on one color in their works. I argue that the blue color has thus become an inherent part of Novat's visual identity: his signature.

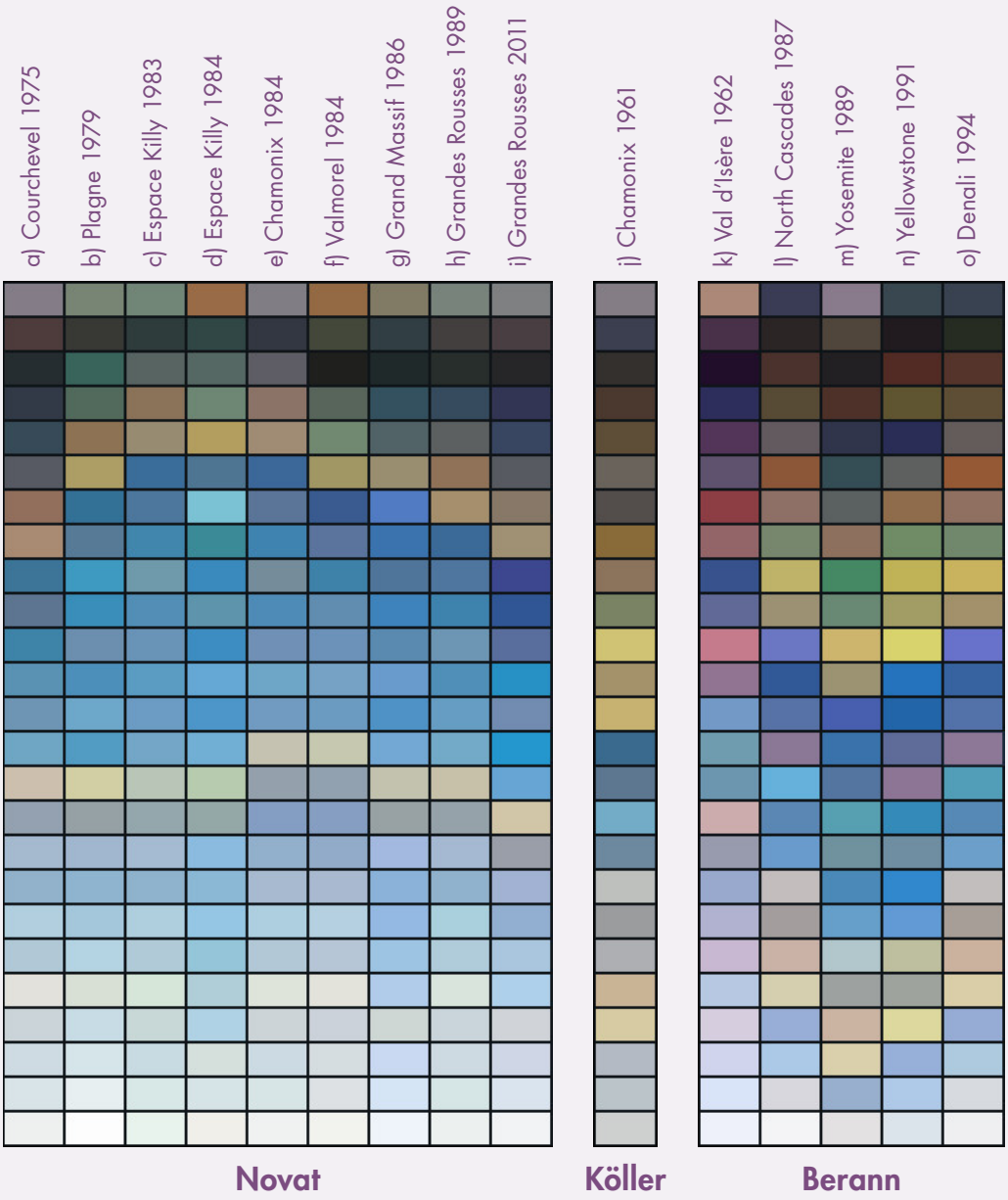


Figure 7. Color palettes extracted from the panorama maps displayed in Figure 9. Note how an important part of Novat's palettes (a–i) is dedicated to snow and its blue shades, whereas Köller (j) and Berann (k–o) make use of more heterogeneous palettes. Note that *Grandes Rousses* 2011 (i) is a posthumous rework by Novat's son. Blues used in the rework are warmer (with a higher red component), hence the unusual purple tones.

Aside from being an artistic choice, the use of blue in winter panoramas is logical. Shadows cast onto snow are indeed blue under a clear sky, because of the scattering of ambient light. In Novat's paintings, shades of blue provide cues about the relief of the terrain, mimicking complex lighting phenomena such as shading, shadows, and inter-reflections (indirect light on a surface), drawing the viewer's attention to specific areas of the terrain.

Novat changed both the lightness and the hue of this blue to achieve his goal. These changes are implicitly guided by the laws of physics. He added more blue and lowered the contrast by lightening colors to depict atmospheric perspective in the background, conversely adding more red in the foreground. He modified his blues by adding a hint of yellow to depict color bleeding induced by trees, and to

Figure 8. Color pencils are used to support shadows (left), bases of trees (middle), and rocks (right). Close-ups of *Grandes Rousses*, Arthur & Pierre Novat 2011.

give a turquoise hue to glaciers. These color adjustments required a solid knowledge of the mountain and a careful observation of the landscape.

Another explanation for the variations in the shades of blue is the use by Novat of different media in a single painting. He mainly used watercolor pencils and gouache sprayed with an airbrush or directly applied with paintbrushes. According to Novat, Novat, and Belluard (2013), Pierre Novat painted entire regions, including details, rather than working on the whole panorama one layer at a time. For this reason, and because using an airbrush involves a drying time of about five minutes per coat, Novat kept switching between media and colors. As a result, the shade of blue used for a given feature is never exactly the same across the panorama.

Pencils were used to support the shapes of shadows and the slopes hinted by the trees and the edges of rocks, giving strength and contrast to the painting. To smooth the result, Novat used his airbrush to spray paint or water onto these harsh lines, blending them and the underlying blue together (Figure 8), again impacting its hue.

Client wishes are also a factor. For instance, clients asked for warmer colors in the 1984 panorama of Espace Killy (Figure 9, d) than those used for the 1983 version (Figure 9, c). In 1989 this change was reverted to the 1983 tones.

6. STYLIZED REALISM OR REALISTIC STYLIZATION

In the media, the style of Pierre Novat is often described as "hyperrealistic" (France 3 Alpes Sud 1992). This statement is ironic considering how much Novat bends reality in his panoramas. He locally deforms the topography and also exaggerates lighting phenomena. The goals are numerous: to hide or reveal details of the surface; to draw attention to a given area; and to discourage skiing in dangerous areas.

Regardless of these deformations and infringements, the result appears plausible even to locals and expert users. This feeling of "realness" comes from Novat's great attention to detail, his retention of important landscape features, and his thorough depiction of complex lighting phenomena.

PLAUSIBLE DEFORMATION OF THE TOPOGRAPHY

Novat's panoramas make it easier for an uninitiated audience to understand the mountain terrain. It is represented from the skiers' point of view as they approach the slopes. More space is dedicated to areas that are of particular interest to them. Entire mountains are rotated or moved apart, to reveal all ski areas in one painting. Novat deforms the shape of the mountain while considering skier traffic, accessibility, number of pistes in the area, and their difficulty ratings.

Because features of the terrain are often represented from their most well-known viewpoints or from the viewpoint one has when skiing, both the visitors as well as locals still recognize the landscape. According to Arthur Novat,

a) Novat - *Courchevel* 1975

b) Novat - *Plagne* 1979

c) Novat - *Espace Killy* 1983

d) Novat - *Espace Killy* 1984

e) Novat - *Chamonix* 1984

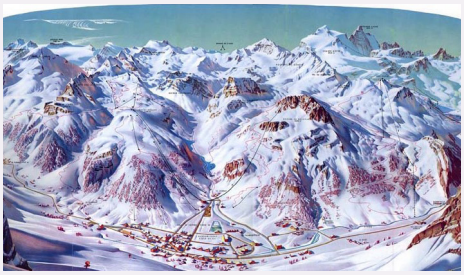
f) Novat - *Valmorel* 1984

g) Novat - *Grand Massif* 1986

h) Novat - *Grandes Rousses* 1989

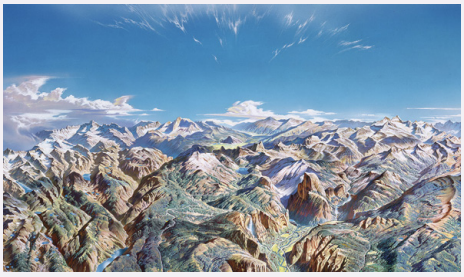
i) Novat - *Grandes Rousses* 2011

j) Köller - *Chamonix* 1961



k) Berann - *Val d'Isère* 1962

l) Berann - *North Cascades* 1987



m) Berann - *Yosemite* 1989

n) Berann - *Yellowstone* 1991

o) Berann - *Denali* 1994

Figure 9. Panoramas used to extract the color palettes in Figure 7. Panoramas displayed here are scaled and cropped to fill the available space without distorting the image.

people sometimes do not notice these deformations. Pierre Novat interpolated seamlessly between several viewpoints, as if different cameras captured the landscape. He sometimes filled the gaps using his imagination, leading to what his son calls "panoramic cubism." The representation of the mountain conveyed by one panorama remains plausible, leading to Novat's style being mistakenly described as realistic.

Deformations are also necessary because the depicted region rarely fits within the field of view of an undistorted panorama. The angle of view can be huge and irregular. Figure 10 is a 2D map of the Espace Killy area (see Figure 5 for the panorama by Novat). In the panorama, the main viewpoint is above Chevril Lake (1). Note that the angle of view (blue arrows) is about 180° (from A to H, through 1). This allows Novat to place the valley between Val d'Isère (3) and "Pointe de la Galise" (A) on the same map as Tignes (4). Although the two valleys are almost aligned on the map, they are opposed on the panorama. The angle of view is also wider on the left part: a wider area is compressed into an equal portion of the panorama. This would have been impossible using a regular perspective view (green dashed arrow) instead.

Figure 11 displays the view one can enjoy from Col de Fresse (5) when looking at Grande Motte (F) and Grande Casse (G). Both Val d'Isère (3) and Tignes (4) have been equipped to reach this col (pass), turning it into a central junction for the resort. This view is then familiar to users of Espace Killy. It also strongly resembles what skiers experience when going up to the Grande Motte's summit using the Grande Motte chairlift (6). These reasons motivated Novat to locally change the viewpoint. To achieve this, he performed several different rotations. First, the whole ridge was rotated about F through around 60°, thus facing the main viewpoint of the panorama (1). Then, each peak was individually rotated about its vertical axis to present its most recognizable profile.

Nevertheless, deforming the topography and rotating mountains are not characteristics of Novat's style alone: other panoramists have similar approaches, e.g., the Teton Range in Berann's Yellowstone panorama (Patterson 2000, 14), although Novat may make more extensive use of these techniques. Deforming the terrain allows the artist to depict terrain features that would otherwise be invisible, in such a way that viewers can more easily recognize the relief.

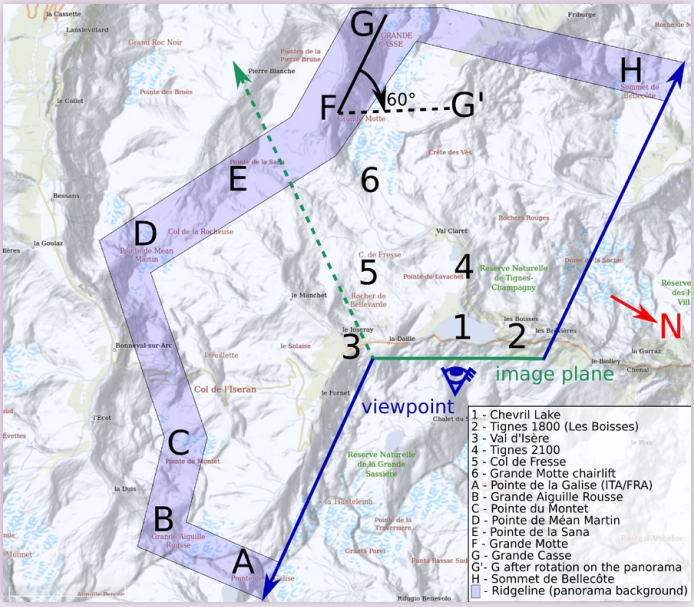


Figure 10. 2D map of the area depicted in the Espace Killy panorama (Figure 5) with important landmarks captioned. The red arrow (N) indicates north. Note the wide angle of view used, allowing Novat to place the valley between Val d'Isère (3) and "Pointe de la Galise" (A) on the same map as Tignes (4). The angle of view chosen is wider on the left than on the right of the panorama, yet the deformation appears natural. The ridge F–G is rotated through around 60° about F, so that it faces the viewer. Still, Novat depicted the left sides of each peak, as if viewed from the Grande Motte lift (6).

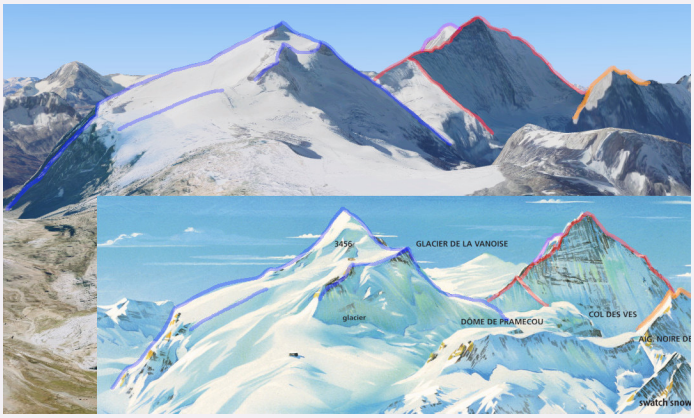


Figure 11. Top: 3D view of Grande Motte (blue) and Grande Casse (red) as if viewed from Col de Fresse (5), a crucial part of the resort. Bottom: Close-up of *Espace Killy*, Pierre Novat, 1984 (Figure 5). These two peaks are rotated about their vertical axis to present a more familiar profile to skiers.

For instance, Berann exaggerated heights, projected the terrain onto a cylinder and used a quasi-orthographic view, leading to frontal majestic backgrounds typical of his style (Patterson 2000). On the other hand, Novat used a multi-perspective (graphical) projection, and varied

the positions and heights of the viewpoints. Although the final look is different, the goal remains the same.

The complex nature of the mountain topography, especially in the Alps, makes these mandatory deformations difficult. I would argue that deforming the terrain is the main difficulty when creating a panorama. Novat excelled in this field for a variety of reasons, the influences of which are difficult to assess. His extensive knowledge of the regions represented, especially the French Alps, his ability to interpret topographic maps as 3D landscapes, and his skiing and skydiving experience, most certainly played a major role.

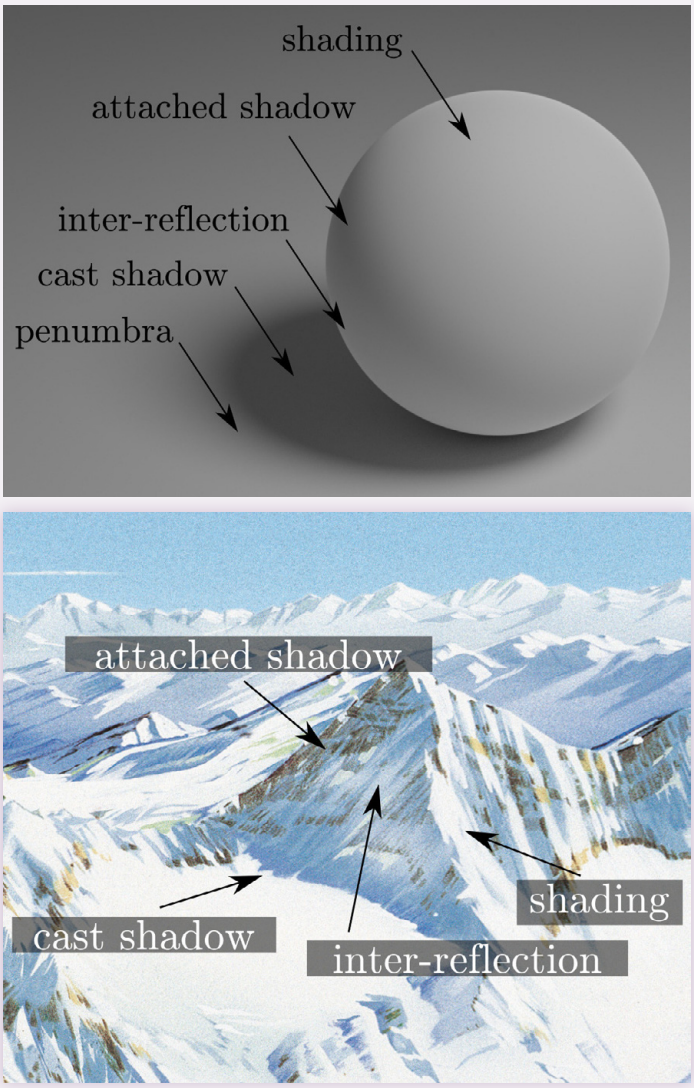


Figure 12. Lighting terminology as defined by Mamassian, Knill, and Kersten (1998). Top: A rendering of a diffuse sphere. Bottom: The terminology applied to a close-up of *Grandes Rousses*, Arthur & Pierre Novat 2011. Note that a penumbra does not occur with strong directional lights, e.g., the sun, hence its absence in Novat's panoramas.

LIGHTING EFFECTS

When discussing lighting effects, and specifically shadows, I will use the terminology by Mamassian, Knill, and Kersten (1998; Figure 12). Shading is a variation of the reflected light on a surface. For diffuse surfaces, the shading is governed by the Lambert's cosine law (i.e., the orientation of the surface with respect to the direction of light). An attached shadow is the part of the surface where the light is occluded by the object itself, whereas objects occluding the light source cause cast shadows to appear on remote surfaces. Inter-reflection is a phenomenon caused by light bouncing off surrounding surfaces. The penumbra is the region of the cast shadow where the light source is partly visible.

Lighting Design

Panoramists often deviate from common cartographic conventions (Imhof 1982). For instance, they carefully choose orientations used in panoramas, and rarely align them with the north. Regarding lighting, they depict cast shadows in their paintings, rather than the simplified hill-shading often used in 2D mapping. The carefully considered play of light depicted in Novat's panoramas is another key element of his style. It plays a crucial role in the plausibility and understanding of the panoramic map.

A panorama displays ideal weather conditions, at either sunset or sunrise. However, a completely realistic depiction of the effects of the light direction and low sun angle at these times can impair the readability of the map. Therefore, panoramists must invent new ways of shading the terrain surface, casting shadows, and depicting complex lighting effects such as indirect illumination. To that end, Novat performs with his brushes the work of lighting designers with their lamps, or lighting artists using their 3D software.

Careful lighting design prevents shadows cast by the sun from masking important areas, and provides enough contrast for features parallel to the light direction. These are also good reasons not to use aerial photographs in place of panorama maps, as they would suffer from these problems. Novat had numerous techniques to solve these issues.

Lighting Inconsistencies

Novat changed the local direction of light in his panoramas. Figure 13 shows an example of how the light is

aligned differently depending on the surface orientation of features. I estimated these local light directions in several areas, depicted by arrows pointing towards the imaginary sun used to create lighting effects in that area. For instance, if the direction of light γ_1 were used to shade the valley in the rectangle, understanding the terrain would be difficult. Given their slopes, both sides of the valley would have about the same shading, diminishing contrast. Novat thus locally aligned the light with the illuminated face using light direction γ_3.

These variations in the light direction allow for a precise control over the shading. Illuminated slopes are brightened and shadowed ones darkened, thus increasing contrast. Although not based in physical reality, this particular way of lighting the scene does not impair our perception of shape, as the human visual system is rather insensitive to lighting inconsistencies (Ostrovsky, Cavanagh, and Sinha 2005). In fact, maximizing local contrast on the surface ensures a better shape depiction, and locally varying the direction of light has proven to be an efficient way to achieve this goal (Jenny 2001; Marston and Jenny 2015; Mestres et al. 2021). Manual relief shading for maps is also based on locally varying the light direction. It has inspired cartographic research that has produced numerous digital techniques since the foundational work of Brassel (1974). This research work on relief shading for digital terrain visualization is discussed in more detail in Section 8.

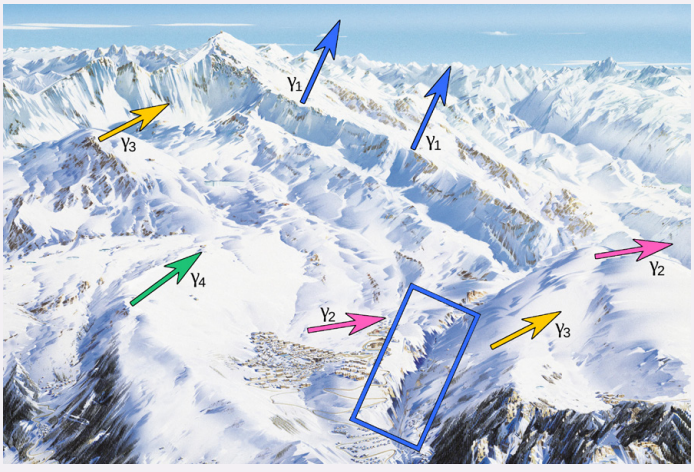


Figure 13. The direction of light varies locally across the panorama. Arrows point towards the light source (i.e., the sun). Arrows with the same color (and label) point in the same direction. Note that small variations occurr in individual features, such as the foreground hill at the right where different lighting directions are used. Close-up of *Grandes Rousses*, Arthur & Pierre Novat 2011.

Changing the direction of light not only helps with the shading. It also allows for the control of shadows, whose positions are important to recover spatial arrangement and to underline important features of the terrain.

Cast Shadows

Figure 14 presents examples in which Novat used cast shadows to depict terrain details on shadowed slopes that would not be directly exposed to sunlight. In reality, cast shadows cannot be inside other shadows (attached or cast).

Figure 14. Novat used fine-scale cast shadows inside attached shadows of larger features. They improve the contrast of already shadowed areas, thus revealing masked terrain features. Close-ups of (top) *Espace Killy*, Pierre Novat, 1983 and (bottom) *Courchevel*, Pierre Novat, 1984.

Still, Novat allowed small features within the shadowed slopes of larger landforms to cast their own shadows. These multi-scale shadows were painted from the coarser to the finer scale. The increase in contrast caused by an additional layer of fine-scale shadows helps with the readability of even the smallest details and enhances the depiction of the relief.

Casting shadows on important parts of the terrain that should stay clearly legible would cause something that the visual perception community calls *masking*. Masking is a phenomenon in which another stimulus (the mask) makes it difficult for the human visual system to recover information (in our case, shape and spatial arrangement; Legge and Foley 1980).

Figure 15. Novat ended the cast shadow just above the road to avoid masking it. The shape of the shadow therefore follows the road layout, highlighting it. Close-up of *Mégève*, Pierre Novat, 1986.

Novat instinctively altered the shape of shadows to prevent masking. Strong shadows were stopped shortly after the bottom of slopes or before important elements of the panorama (see Figure 15 for an example). It allowed him to highlight abrupt changes in the slope that the user of the map should be aware of. Also, Novat's shadows are generally brighter than those in real life or than would be found in realistic renderings. It is again a way to prevent masking while still painting shadowed areas in a convincing way.

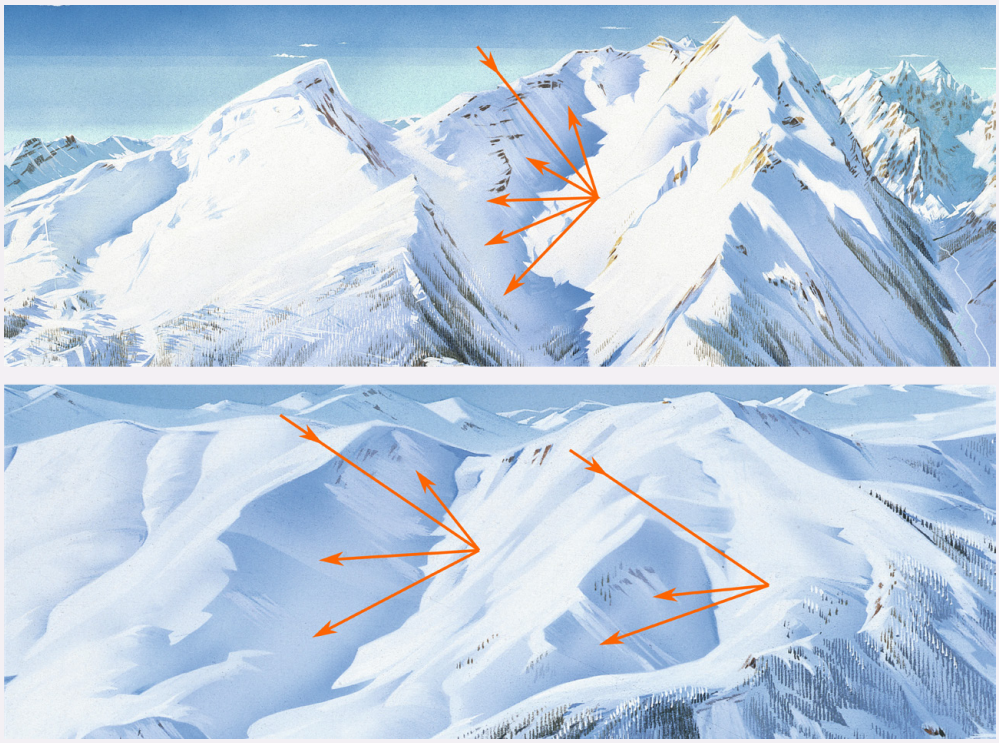


Figure 16. Examples of indirect illumination from inter-reflections in Novat's work. Arrows represent light rays. Inter-reflections are caused by the light bouncing off slopes facing the light, thus brightening opposing slopes. Close-ups of (top) *Puy Saint-Vincent*, Pierre Novat, 1992, and (bottom) *Val d'Allos*, Pierre Novat, 1987.

Inter-reflections

Novat's use of inter-reflections (i.e., indirect illumination) is a practical means of relighting dark areas in a way that feels natural for the viewer. For instance, in a valley, we expect inter-reflections to be painted on the slope opposing the one exposed to the sunlight. See in Figure 16 how the shadows are brightened by the faces that reflect direct lighting. Novat brightened mostly the center of shadows. He maintained high contrast by keeping the bottom part dark. Novat developed his treatment of inter-reflections starting with his first panorama. We can see on his alteration of Val d'Isère by Berann (Figures 4 and 17) that although Novat integrated Tignes in the style of Berann, he also already had his own style.

Most of the complex lighting effects worth depicting in a panorama were captured in the photographs taken by Novat during his preliminary study of an area. Using these as a base for painting, Novat retained a certain physical accuracy, making the scene even more plausible. But

Figure 17. Novat's treatment of inter-reflections (left) is more subtle than Berann's (right). The blue of the shadowed snow is lightened, creating a soft gradient whereas Berann used complementary shades, creating a stark contrast. Close-ups of *Val d'Isère*, Berann (with alterations by Novat) 1962.

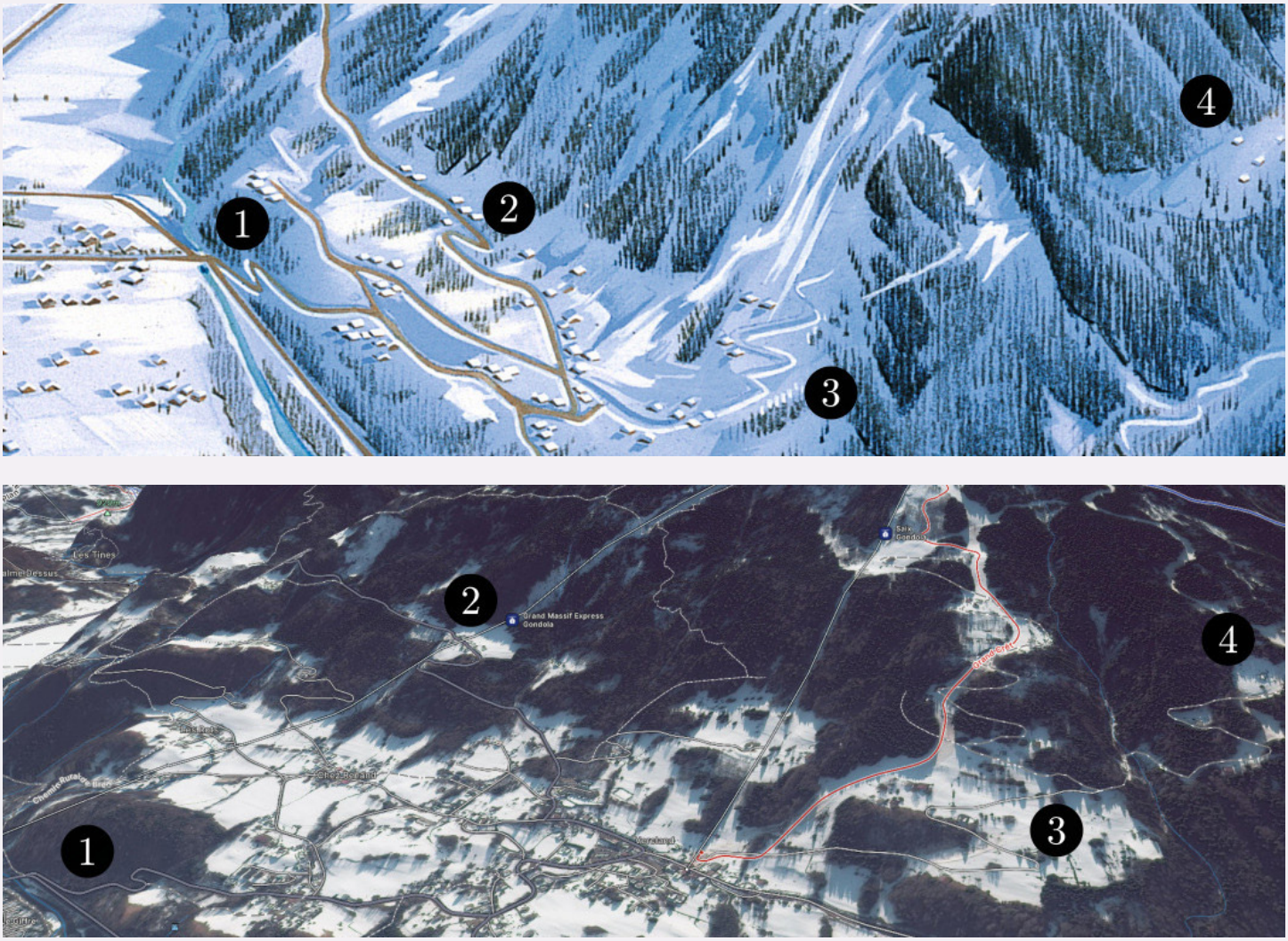


Figure 18. Top: Close-up of *Grand Massif*, Pierre Novat, 1986. Bottom: Satellite view of the same area. Note how Novat diminished the tree coverage density in his painting; as a result, the terrain remains visible.

inter-reflections were also sometimes added solely because they were convenient for terrain depiction; again, another reason not to describe Novat's panoramas as "realistic." Intuition played an important role in his painting, and inter-reflections were often placed "where they feel right," says Arthur Novat.

Atmospheric Perspective

Sunlight is scattered by particles in the atmosphere. Light that has a wavelength that is shorter than or similar to these particles is scattered more. This phenomenon is called Rayleigh scattering in optics, and atmospheric or aerial perspective in cartography and painting (Jenny and Patterson 2020). It is responsible for a decrease in contrast for distant objects and for giving them a bluish aspect, as blue light corresponds to the short wavelengths of the human-visible spectrum.

To help us gauge the expanse of the Alps, Novat painted not only the resort, but also the scenery that surrounds it. However, he drew the attention of the viewer to the resort with a clever use of atmospheric perspective in the background. For instance, Mont Blanc towers over the scene in the background of Figure 1. Aerial perspective makes it appear far away, reducing its importance without having to omit the emblematic summit. For areas inside the resort, the contrast is preserved, leaving it to stand out within reach of the skier, distinct from the background that is veiled by a layer of haze. Thanks to this technique, the viewer focuses on important parts of the panorama.

7. SURFACE TEXTURE

I HAVE PRESENTED the terrain deformation and use of lighting effects elements that are at the heart of Pierre Novat's style. However, these elements alone would lead to a very bland representation of the scene. Novat populated his panoramas with elements painted on top of the terrain surface: trees, rocks, roads, and buildings. They texture the mountain and serve an aesthetic as well as an informative purpose.

TREES

Some mountainous areas are covered with trees, so Novat decreased the tree coverage density to avoid losing terrain information in his paintings (Figure 18). His treatment of trees differed substantially from that of other artists. For example, James Niehues is known for painting each tree individually (Figure 19). Conversely, Novat used color pencils to depict trees. They were pencilled directly onto the snow, hatched to form bands of trees. A few trees are enough to represent a grove, add more of them and you have a forest. Their colors depend on their species: deep greens, almost black, for the spruces and firs; light browns and yellows for larches dusted with the first snow of the season. Larches are conifers, as are firs, but they lose their needles during fall, enabling light rays to pass through their branches. As a result, they are only lightly sketched over the snow in sunny areas (Figure 20, a).

Trees were depicted by more than just flat color pencil strokes onto the canvas. Their colors blend with the

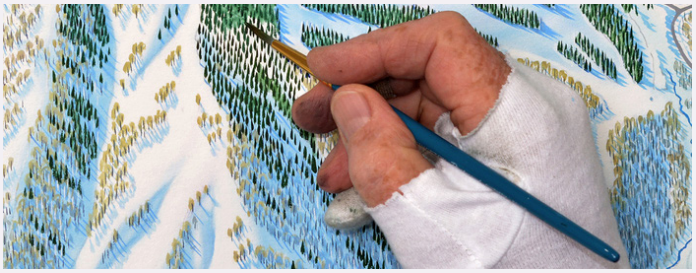


Figure 19. James Niehues painting trees one by one. Figure adapted from the interview by Kelly (2021). See how Niehues's trees differ from Novat's in Figure 8, middle, and Figure 20.

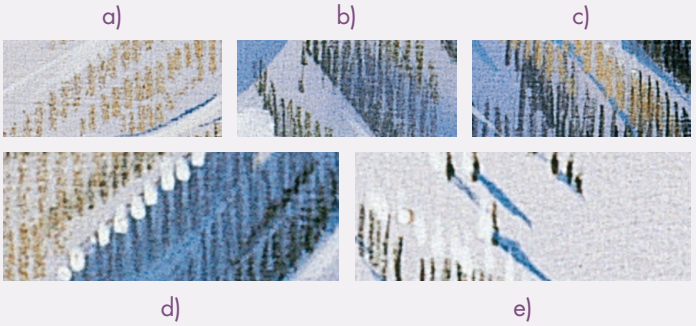


Figure 20. Novat's treatment of trees differed from one species to another. Larches (a) were lightly sketched over the snow. Novat smoothed trees in shadows with his airbrush by spraying them with paint or water, blending their color with the blue of the snow (b). Trees catch the light (c) and can be covered in snow (d). They cast shadows when alone or at the edge of a forest (e). Close-ups of *Réallon*, Pierre Novat, 1990.

Figure 21. Aiguille du Goûter. Left: Photograph (© Antonio Giani). Right: Closeup of *Chamonix*, Pierre Novat, 1992. Note how the depiction is accurate on the painting, with cracks in the rocks clearly visible.

surroundings (Figure 20, b) and they catch light and shadows (Figure 20, c). Some are covered with snow (Figure 20, d). Those that stand alone or are at the edge of a forest cast shadows on the ground (Figure 20, e).

Trees are exempted from perspective projection—they are depicted as if viewed from an orthographic camera. As a result, their height becomes strongly exaggerated in the background. They are always drawn vertically and distributed along the slope. The alignment of the trees thus becomes a visual cue giving precious implicit information about the relief of the terrain beneath them.

ROCKS

Rocks are mainly visible when the slope is steep or when they protrude from the ground. In Novat's panoramas, they are depicted on important landmarks that must be recognized as faithful to reality. For example, note how the characteristic horizontal and vertical cracks in the rocks are reproduced in Novat's depiction of Aiguille du Goûter seen in Figure 21.

They are also a practical way to implicitly inform skiers about the danger of the terrain. In difficult areas, rocks that are invisible because of snow are shown in the painting, to act as warnings. For easy ski trails, the terrain is often smoothed and rocks omitted so that beginners do not hesitate to ski there.

Regarding color, rocks were painted in very different shades from one panorama to the next. Although influenced by the complex geology of the Alps and the different types of rocks, the color depends also on the hour of the day chosen to represent the scene. As mentioned in Section 4, prior to the creation of a panorama, photographs

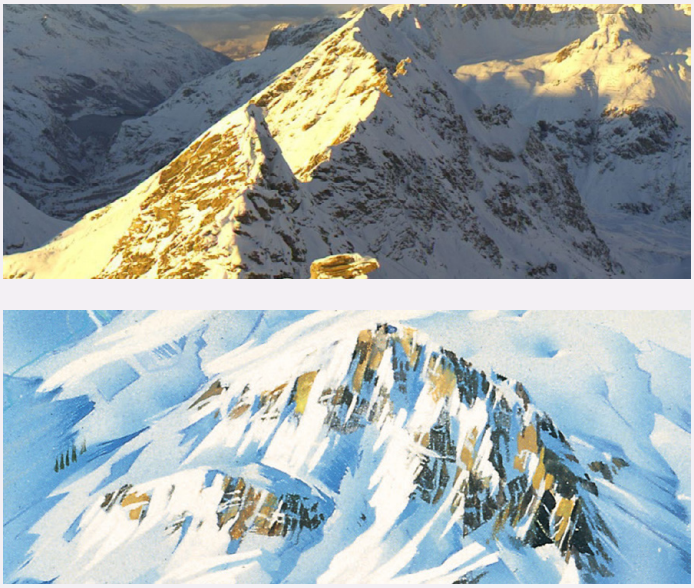


Figure 22. Top: Photograph of rocks above Val d'Isère village at sunset from a webcam in the resort (© Val d'Isère Tourisme). Bottom: Close-up of *Espace Killy*, Pierre Novat, 1984. The shades of brown and yellow are reproduced directly from the preliminary photographs taken by Novat.

were taken by flying over the area. These shots were taken in the morning or evening when the sun was very low. As a result, rocks exhibit vivid colors such as warm browns, yellows, and reds. See Figure 22 for an example on the Espace Killy panorama. The colors used for rocks in the painting are very similar to those seen in the modern photograph. Note how the snow is kept white, increasing contrast even more, as opposed to the photograph, in which it is yellow.

ROADS

Roads on Novat's panoramas are not applied as a layer on top of the panorama after the painting is finished, as is the

case with the labels. While this might work well for a 2D map, for a panorama, roads need to be part of the painting itself.

In Novat's style, they are slightly lowered with respect to the surface of the terrain, as if snowbanks were framing them. To achieve this 3D look they were outlined with white paint on one side, particularly noticeable in shadowed areas, and with a dark blue stroke on the other (see Figure 23). Roads inform the viewer that different places in the panoramas are connected. They are enlarged to be clearly understood, but their shapes are also sometimes abstracted. Depicting only some of the roads has an impact on routes chosen by visitors. It helps to guide them towards spots considered of interest for the resort, while keeping them away from residential areas and competing villages.

Figure 23. A road. Note how its path is highlighted using shadows and touches of white. Close-up of *Mégève*, Pierre Novat, 1986.

BUILDINGS

Like roads, chalets and buildings are 3D elements that have been integrated into the painting, not just layered above it. They cast shadows and are always represented with snow on their roofs.

Where roads are always exaggerated in size and sometimes abstracted, buildings are surprisingly accurate. Figure 24 compares Aussois on the 1993 panorama with a photograph taken in 2011. The village has undergone change, but some buildings can still be clearly identified. Indeed, characteristic buildings (e.g., city halls, churches) needed to be recognizable, as well as the ones visible from the road when driving, as they can be useful landmarks for visitors.

Often, Novat's commissions were updates to include newly constructed buildings and facilities in existing panoramas.

Figure 24. Top: The village of Aussois in 2011 (© Florian Pépellin CC-BY-SA 3.0). Bottom: Its 1993 painted version by Novat. The church and some houses are still recognizable today.

Clients regularly requested that their homes appear on new and updated panoramas, which required painting with enough precision to depict a small chalet.

8. TOWARDS DIGITAL AND STYLIZED PANORAMAS

Producing a hand-painted panorama is a challenging task, involving a broad range of skills. Even for masters such as Berann or Novat, the production time for large paintings can take up to several months (Patterson 2000; Novat, Novat, and Belluard 2013). Panoramists, though experts at crafting beautiful aerial maps of the mountain, are now a dwindling profession due to these constraints.

Indeed, ski resorts rely more and more on Computer-Generated Imagery (CGI) to produce panoramas. Figures 25 and 26 display comparisons between Novat's hand-painted panoramas of Valmorel and Réallon and versions created by the company Kaliblue. Although fast, 3D rendering systems lack the editing tools to enable the creation of panoramas of similar artistic quality—they offer a limited range of styles. Artists are often required to

Figure 25. Valmorel. Top: Novat's version (1984). Bottom: Kaliblue's panorama for season 2021–2022. © Kaliblue.

manually or digitally repaint parts of the rendered images to achieve the desired result (as seems to be the case in the panoramas by Kaliblue).

The cartographic and computer graphics research communities share common goals regarding terrain representation (Kennelly and Kimerling 2006). Both are tackling the challenge of enabling the creation of clear and stylized digital mountain panoramas. The main focus so far has been the style of Berann. Based on his artworks, rules that define his style are inferred, then translated into algorithms for image synthesis. Both the painterly rendering and the terrain deformations are currently being explored. Full rendering systems (Bratkova, Shirley, and Thompson 2009; Brown and Samavati 2017) mimic Berann's style regarding shading and surface texture. They also globally curve the terrain so that foreground landmarks do not mask background features. Jenny and Jenny (2013) used an early style transfer method, example-based texture synthesis, to apply Berann's style to 3D rendered terrains. This area of computer graphics has made significant progress since that time and continues to be a promising avenue of research—see the stylized panorama in Figures 11 and 12 of Futschik et al. (2021). Still, as these methods are automatic, they lack artistic control, a crucial feature for creating expressive renderings.

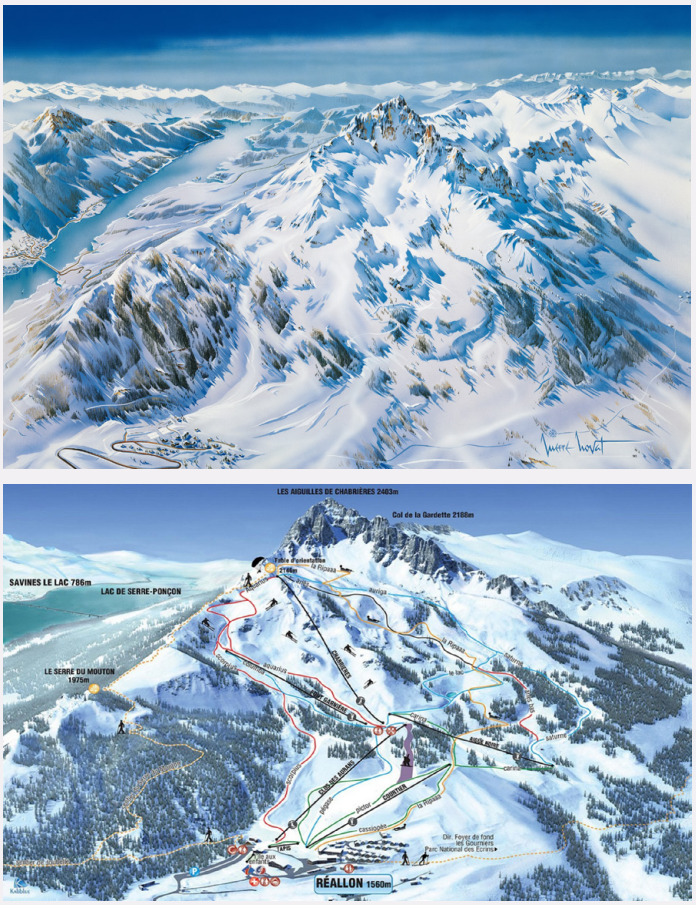


Figure 26. Réallon. Top: Novat's version (1990). Bottom: Kaliblue's panorama for the 2011–2012 season. © Kaliblue.

Automatic (Degener and Klein 2009) and computer-assisted (Jenny et al. 2011) methods have been proposed to deform the topography of the terrain locally, in the spirit of Berann. These deformations could be combined with the above-mentioned rendering techniques for convincing results, but to this date and to my knowledge, little work has been conducted in this regard.

More generally, digital artists can enhance the depiction of terrain shape using shading models that locally modify the intensity of the shading at the surface of objects (or terrain). Cartographic research often takes inspiration from hand-shaded relief while computer graphics research focuses on natural phenomena and human visual system properties. Nevertheless, the work of both communities sometimes overlaps.

Accessibility Shading methods (Miller 1994; Pharr and Green 2004) adapt shading with respect to the surrounding geometry, darkening areas that are difficult to reach. Kennelly and Stewart (2006) use the sky model

formulation to enhance terrain depiction. These were approximations assuming a uniform environment, though the same authors later (2014) address this issue by enabling the use of arbitrary sky models. Other methods control shading by combining images rendered using different light directions (Jenny 2001; Marston and Jenny 2015), or by varying the light direction before rendering (Brassel 1974; Rusinkiewicz, Burns, and DeCarlo 2006; Vergne et al. 2009; Veronesi and Hurni 2015; Mestres et al. 2021), similarly to what manual panoramists would do. The work of Jenny et al. (2021) is a notable exception that uses deep learning to produce shaded relief images from manual examples.

These approaches have much in common in terms of technique and purpose. In this regard, it seems beneficial to foster collaboration between the two communities of cartography and computer graphics, which hopefully will yield fruitful results for 3D terrain rendering and landscape visualization.

9. CONCLUSION

In this paper, I have described the characteristic style of the painter and panoramist Pierre Novat. We have seen how Novat's panoramas feature a deformed representation of the landscape that is viewer-centric. I presented his unique treatment of lighting phenomena, which was aimed at a clear depiction of the relief. I also showed how he used surface texture elements to convey crucial information. An examination of these three elements—terrain deformation, lighting effects, and surface texture—is a necessary first step for an in-depth understanding of the panoramas by Atelier Novat. Hopefully, this study will help to safeguard parts of Novat's knowledge and give contemporary artists insights about panoramic maps designed in the style of Novat.

As a marketing tool for resorts, Novat's panoramas played an important role in the expansion of alpine skiing in France. Still in use today, they respond to the clients' requests by reconciling commercial considerations with the topography of the area. When creating a panorama, compromises must be made, and Novat clearly excelled at the task.

Because many ski areas are rapidly evolving into "four season" mountain resorts, they have new demands, which the traditional techniques used by panoramists cannot meet. Computer-assisted solutions for the creation of panoramic maps are therefore gaining more attention. Rendering systems are now used to generate mountain panoramas that are then digitally retouched by artists to fulfill the clients' desiderata. Automatic results of a quality equivalent to a hand-painted map are not within reach yet, and much work remains to be done to provide digital artists with tools to express their styles. This should prove to be an exciting avenue of future work in both the computer graphics and cartographic communities. The perpetuation of panoramists' know-how is at stake.

REFERENCES

Balzarini, Raffaella, Anne Dalmasso, and Maxime Murat. 2015. "A Study on Mental Representations for Realistic Visualization: The Particular Case of Ski Trail Mapping." *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XL-3/W3: 495–502. **https://doi.org/10.5194/isprsarchives-XL-3-W3-495-2015**.

Balzarini, Raffaella, and Maxime Murat. 2016. "The Effectiveness of Panoramic Maps Design: A Preliminary Study Based on Mobile Eye-Tracking." *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XLI-B2: 361–368. **https://doi.org/10.5194/isprs-archives-XLI-B2-361-2016**.

Bennett, Todd, Ben Farrow, and Jason Blevins. 2019. *The Man Behind The Maps*. Long Beach, CA: Open Road Ski Company.

Brassel, Kurt. 1974. "A Model for Automatic Hill-Shading." *The American Cartographer* 1 (1): 15–27. https://doi.org/10.1559/152304074784107818.

Bratkova, Margarita, Peter Shirley, and William B. Thompson. 2009. "Artistic Rendering of Mountainous Terrain." *ACM Transactions on Graphics* 28 (4): 102. https://doi.org/10.1145/1559755.1559759.

Brown, S. Alex, and Faramarz Samavati. 2017. "Real-Time Panorama Maps." In *NPAR '17: Proceedings of the Symposium on Non-Photorealistic Animation and Rendering*, edited by Stephen N. Spencer, Article 6. Los Angeles, California: Association for Computing Machinery. https://doi.org/10.1145/3092919.3092922.

Dauer, Tom. 2020. *The Alps in Panoramic Paintings*. Munich: Prestel.

Degener, Patrick, and Reinhard Klein. 2009. "A Variational Approach for Automatic Generation of Panoramic Maps." *ACM Transactions on Graphics* 28 (1): 2. https://doi.org/10.1145/1477926.1477928.

France 3 Alpes Sud. 1992. "Pierre Novat, panoramiste de montagne." March 21, 1992. Accessed March 17, 2022. https://fresques.ina.fr/montagnes/fiche-media/Montag00126/pierre-novatpanoramiste-de-montagne.html.

Futschik, D., M. Kučera, M. Lukáč, Z. Wang, E. Shechtman, and D. Sýkora. 2021. "STALP: Style Transfer with Auxiliary Limited Pairing." *Computer Graphics Forum* 40 (2): 563–573. https://doi.org/10.1111/cgf.142655.

Heckbert, Paul. 1982. "Color Image Quantization for Frame Buffer Display." In *Proceedings of the 9th Annual Conference on Computer Graphics and Interactive Techniques*, 297–307. New York: Association for Computing Machinery. https://doi.org/10.1145/800064.801294.

Imhof, Eduard. 1982. Cartographic Relief Presentation. Edited by Harry J. Steward. Berlin: De Gruyter. https://doi.org/doi:10.1515/9783110844016.

Jenny, Bernhard. 2001. "An Interactive Approach to Analytical Relief Shading." *Cartographica* 38 (1–2): 67–75. https://doi.org/10.3138/F722-0825-3142-HW05.

Jenny, Bernhard, Magnus Heitzler, Dilpreet Singh, Marianna Farmakis-Serebryakova, Jeffery Chieh Liu, and Lorenz Hurni. 2021. "Cartographic Relief Shading with Neural Networks." *IEEE Transactions on Visualization and Computer Graphics* 27 (2): 1225–1235. https://doi.org/10.1109/TVCG.2020.3030456.

Jenny, Bernhard, and Tom Patterson. 2020. "Aerial Perspective for Shaded Relief." *Cartography and Geographic Information Science* 48 (1): 21–28. https://doi.org/10.1080/15230406.2020.1813052.

Jenny, Helen, and Bernhard Jenny. 2013. "Challenges in Adapting Example-based Texture Synthesis for Panoramic Map Creation: a Case Study." *Cartography and Geographic Information Science* 40 (4): 297–304. https://doi.org/10.1080/15230406.2013.795001.

Jenny, Helen, Bernhard Jenny, William E. Cartwright, and Lorenz Hurni. 2011. "Interactive Local Terrain Deformation Inspired by Hand-painted Panoramas." *The Cartographic Journal* 48 (1): 11–20. https://doi.org/10.1179/1743277411Y.0000000002.

Kast, Günter, and Robert Fischer. 2019. "I Paint over Problem Areas." *Tirol*. Accessed March 17, 2022. https://www.tyrol.com/blog/bpeople/i-paint-over-problem-areas.

Kelly, Tom. 2021. "James Niehues: Man Behind the Maps." *Ski Utah*. Accessed May 16, 2022. https://www.skiutah.com/blog/authors/tom-kelly/james-niehus-man-behind-the-maps.

Kennelly, Patrick J., and A. Jon Kimerling. 2006. "Non-Photorealistic Rendering and Terrain Representation." *Cartographic Perspectives* 54: 35–54. https://doi.org/10.14714/CP54.345.

Kennelly, Patrick J., and A. James Stewart. 2006. "A Uniform Sky Illumination Model to Enhance Shading of Terrain and Urban Areas." *Cartography and Geographic Information Science* 33 (1): 21–36. https://doi.org/10.1559/152304006777323118.

———. 2014. "General Sky Models for Illuminating Terrains." *International Journal of Geographical Information Science* 28 (2): 383–406. https://doi.org/10.1080/13658816.2013.848985.

Legge, Gordon E., and John M. Foley. 1980. "Contrast Masking in Human Vision." *Journal of the Optical Society of America* 70 (12): 1458–1471. https://doi.org/10.1364/JOSA.70.001458.

Mamassian, Pascal, David C. Knill, and Daniel Kersten. 1998. "The Perception of Cast Shadows." *Trends in Cognitive Sciences* 2 (8): 288–295. https://doi.org/10.1016/S1364-6613(98)01204-2.

Marston, Brooke E., and Bernhard Jenny. 2015. "Improving the Representation of Major Landforms in Analytical Relief Shading." *International Journal of Geographical Information Science* 29 (7): 1144–1165. https://doi.org/10.1080/13658816.2015.1009911.

Mestres, Nolan, Romain Vergne, Camille Noûs, and Joëlle Thollot. 2021. "Local Light Alignment for Multi-Scale Shape Depiction." *Computer Graphics Forum* 40 (2): 575–584. https://doi.org/10.1111/cgf.142656.

Miller, Gavin. 1994. "Efficient Algorithms for Local and Global Accessibility Shading." In *Proceedings of the 21st Annual Conference on Computer Graphics and Interactive Techniques*, 319–326. New York: Association for Computing Machinery. https://doi.org/10.1145/192161.192244.

Novat, Frédérique, Arthur Novat, and Laurent Belluard. 2013. *Plans des pistes: Les Domaines Skiables de France Dessinés par Pierre Novat*. Grenoble, France: Glénat.

Oettermann, Stephan. 1997. *The Panorama: History of a Mass Medium*. New York: Zone Books.

Ostrovsky, Yuri, Patrick Cavanagh, and Pawan Sinha. 2005. "Perceiving Illumination Inconsistencies in Scenes." *Perception* 34 (11): 1301–1314. https://doi.org/10.1068/p5418.

Patterson, Tom. 2000. "A View From On High: Heinrich Berann's Panoramas and Landscape Visualization Techniques for the U.S. National Park Service." *Cartographic Perspectives* 36: 38–65. https://doi.org/10.14714/cp36.824.

Pharr, Matt, and Simon Green. 2004. "Ambient Occlusion." In *GPU Gems*, edited by Randima Fernando, 279–292. Boston: Addison-Wesley.

Preppernau, Charles. 2022. "Paint it as You Ski it: an Interview with Ski Resort Map Artist James Niehues." *Cartographic Perspectives* 100: 88–94. https://doi.org/10.14714/CP100.1769.

Rusinkiewicz, Szymon, Michael Burns, and Doug DeCarlo. 2006. "Exaggerated Shading for Depicting Shape and Detail." *ACM Transactions on Graphics* 25 (3): 1199–1205. https://doi.org/10.1145/1141911.1142015.

Tait, Alex. 2010. "Mountain Ski Maps of North America: Preliminary Survey and Analysis of Style." *Cartographic Perspectives* 67: 5–18. https://doi.org/10.14714/CP67.110.

Vergne, Romain, Romain Pacanowski, Pascal Barla, Xavier Granier, and Christophe Schlick. 2009. "Light Warping for Enhanced Surface Depiction." *ACM Transactions on Graphics* 28 (3): 25. https://doi.org/10.1145/1531326.1531331.

Veronesi, Fabio, and Lorenz Hurni. 2015. "A GIS Tool to Increase the Visual Quality of Relief Shading by Automatically Changing the Light Direction." *Computers & Geosciences* 74: 121–127. https://doi.org/10.1016/j.cageo.2014.10.015.

Weyland, Jocko. 2004. "En Piste: An Interview with James Niehues." *Cabinet* 15. Accessed March 17, 2022. https://cabinetmagazine.org/issues/15/weyland_niehues.php.

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Paint it as You Ski it: an Interview with Ski Resort Map Artist James Niehues

Charles Preppernau (he/him)
Esri
geolographer.xyz/contactform

INTRODUCTION

James Niehues has painted more than 200 panoramic resort maps. His 30-year body of work has changed how mountains are represented, and is familiar to many skiers. Charles Preppernau spoke with the artist to discuss mapping techniques, his new book *The Man Behind the Maps*, and his new Great American Landscapes Project. Mr. Niehues' work can be found at **jamesniehues.com**.

The interview has been edited for length and clarity.

INTERVIEW

Charles Preppernau: Your maps are well-liked by both resorts and guests. When a resort comes to you because they're not satisfied with their existing map, what sort of things do they say they find lacking in it?

James Niehues: The ones that don't have a nice map—that have used computer-generated maps—come to me because it really doesn't show off the resort; it's an accurate *diagram* of how to get down the mountain, but it really doesn't show the skier where they are. If the skier looks at that map and then looks around at their environment, they can't tell where they are on the map.

Alyeska

Whenever I do a map, if it's a difficult mountain, and not just one face but multiple faces, I have to do a lot of stretching and twisting of the mountain to show all the sides in one view. The most important thing about that, is that whenever I finally come up with the final composition, it has to, in my mind and the skier's mind, have relative distances and elevations from point to point. I don't just take a run and stretch it across the page so I can show the other side, I do some manipulation that will *credibly* show that. It's something that can't be done with a computer; I'm changing all sorts of perspectives and distances, and they aren't related in any way except how the brain interprets them. I think that's the important thing.

That forced perspective or "unwrapping" the slopes of the mountain is something I'm particularly interested

Breckenridge

in. How do you introduce that distortion while keeping the mountain recognizable?

If you look at a satellite map, the ski runs don't look very inviting. They are very narrow because they're very long. You need to show it as it skis, as it exists. I don't have a formula; I reference hundreds of aerial photographs. I'll start at 2,000 feet above and get some full-frame perspectives from different altitudes. I'll go around the mountain and get perspectives from different points of view. Then I'll drop it lower and start picking up the detail. By the time I get all of these together I can reference the small, detailed photographs and relate them to the larger panoramic photos, and with that start manipulating the mountain until it comes out.

On a blank sheet of paper I'd place all the lifts with the links proportional like they should be or very near so. Once I have them in place and can see the connections, I refer to my photographs and put in all the runs in between. That's pretty much the way that I work.

What sort of techniques have you found, when working with light, that help the reader get a sense of the terrain, especially where it's not receiving direct sunlight?

If it's not receiving direct sunlight I still put in shadows where it's steeper and maybe highlights, even if the sun doesn't touch it. Just give that lighter area to the heaves as they come up. I also work with reflected light; in the shadows, I work in some reflected light on the snow.

Tree shadows are important too; by the angle of the tree shadow, you can tell if it's steep or shallow. But there are a lot of rises where the shadow would move so much that it confuses people, so I don't stay true to the shadowed terrain of trees but change it enough that they can see there's a change in the terrain surface.

Do you incorporate atmospheric effects into this as well?

You know what? Whenever I get tired of painting trees, sometimes I put in a cloud.

Certainly to show the mountain range beyond, I diminish the contrast and detail. To distinguish the height of the mountain, I'll start with the top trees being snow-covered, and as you go down they get greener. Of course, aerial photographs are blue; it's just monochromatic from the air. Hal Shelton had always indicated to me that you paint it as you ski it, not as you work from your aerial photographs, so that helped in my early development.

The atmosphere is a great thing; sometimes I'll bring a whiff of ground fog around the mountain to accentuate something, or if there's an area the client doesn't want people to get out to. A lot of times I like to put in clouds just to show that you rise from below the clouds and get off the lift above them, just to show the feeling of the mountain and its vertical rise.

You've said, "paint it as it skis." Can you unpack that phrase?

I haven't skied every mountain, but I've skied a lot of them. When I relate my experience to the aerials that I've taken, I relate that to other mountains and to how I'd be skiing there even if I hadn't. If a run looks wide and you have lots of room to make turns, you want to widen it and narrow it where it gets tighter. But on a satellite view, it might be very hard to pick up where those changes are. So I think it's just an interpretation of the aerial photography.

In your book, you say you refer to topographic maps quite a bit in this planning phase. When you're looking at a topo map, what are you looking for? To what extent are you looking to translate certain things on that topo map into your panoramic map?

I'll be looking for rock formations; on a topo map you can see where the terrain is a cliff or not, and what I'm looking for is whether there are any runs around it, or maybe a chute through it, so that I can identify it in the photograph. Then I know I'll have their run in the proper spot. So what I'm looking for is deviations in the terrain, and match them up with the aerial photography so that when I interpret it, I interpret it correctly.

Have you ever experimented with a map that was looking purely downhill?

Yeah, and I always thought that would be the way to do it because that's the way the skier's going. The only problem

Keystone

Winter Park / Mary Jane

with it is that the runs are going up-page. It's just hard to relate to it. Plus, what they're really interested in is the base area. All the important ingredients of the resort are in the distance instead of up close. The only one I did was Sunday River, for *Snow Country Magazine*. I thought if

Okemo

there's any one that will work, it would be that one. I really was not happy with the result although it came out to be an interesting illustration.

Are there unique challenges in drawing summer scenes as opposed to winter scenes?

Yeah, there are. I work with the airbrush on snowy terrain, so it's a pretty simple process. With my early summer maps, I tried with the airbrush but it was so unrealistic, so I turned to the brush entirely. I didn't feel my brush rendering was as effective as the airbrush, but I did develop it into a pretty nice style. The latest ones are the Blackcomb and Whistler hiking maps. I was really happy with those. It's maybe a sketchier style, but basically, you need to show where there's grass, brush, rock, or dirt, so it does become quite more involved in summer and fall views. In my fall views, I've always had a problem showing the trees as they are. The Okemo autumn portion is probably my best technique on that.

You talked in your book about how you modified your brushes to try to speed up the drawing of trees.

My predecessors used sponges. I tried that and it just didn't work for me. So then I experimented with cutting the bristles of my brush to make two or three trunks instead of just one. I didn't really like that; it was too repetitive and didn't look natural. From that point, I said, "alright, I'm going to have to draw in every trunk." But I've been in constant experimentation with deciduous trees. Looking back on it, I'm happy with all of it but I do feel like later in my career I got a little too involved in individual deciduous trees, instead of groups of trees.

Another element in all of this is that, ever since the 10th painting, I didn't want every mountain to look the same. I wanted to give a mountain an individual look, so that's the reason for the experimentation. I was very lucky in that I had a contract with *Snow Country Magazine* right off the bat after I got into this. I could experiment on those and not have to worry about the client saying, "Wow that doesn't look like your work".

Did some of your later experiments have better success?

Yes, to some degree. For deciduous trees, they have rounded tops, so I'd use brushes that were rounded on the top. And for meadows and stuff, I'd use a very large brush to put in wider strokes of color. I really got into re-wetting the forest. I'd put in a pattern of trees with a very wet brush, a very dark color, and make my forest. I wouldn't

Crystal

Sun Peaks

even take my brush off the board. I'd just be up and down, making these triangular shapes. I would change my pigment according to whether it was the light side of the mountain or the dark side of the mountain. And then I would come in and re-wet that. The watercolor would flow in between and you'd get a lot of variations in your color. Then I would put in the highlights and the shadowed side, which would usually be snow; blue and white.

I'd like to hear your thoughts on how much freedom you think a mapmaker has in distorting a map, and what kind of responsibility they have to the reader.

I feel that if it's overexaggerated it loses its value immediately because it can be seen and not believed. You have to keep it in the credibility range.

Let me change directions on you a little bit here. I'm working on the Great American Landscape Project. I'm picking out state and national parks and other very popular dynamic areas, and sketching them to the best of my ability to express the best view there can be of that particular subject.

Let's take Yosemite Valley. The most photographed view in the park is the tunnel view, with Bridal Veil Falls on the right and El Capitan on the left. I've flown that area, and I looked at my aerials and thought "You know, I could show the whole valley and include Yosemite Falls, show more of Half Dome, show Royal Arch, and the spires that are on the backside of Bridal Veil Falls, if I did a little manipulating." In my aerials you can't even see what I have sketched; Yosemite Falls is quite hidden by the Three Brothers. So, what I had to do was diminish the Three Brothers a little bit, and pull around Yosemite Falls so that it shows, and then I thought, "Oh the village is right down there so I'll put in the village". So, I peel away some of those tall trees enough to show the village and roads.

Another was Crater Lake, Oregon. This spring we stopped there and it was fabulous, just really dynamic. So I took all these photographs and came back to this point that had

Yosemite Valley

some features along the shoreline that I was really impressed with. Although, from that point, I could not see Mount Thiessen, because it was hidden by a rim on the other side of the lake. So what I did was bring Mount Thiessen out from hiding. This isn't accurate, but it's accurate to the *experience*. It isn't more than 500 yards down the road that you can see [Thiessen], but I had to do some manipulation to show them together. There are also hiking trails that you can't see in the trees, but I put them in, so someone can say "I was on that trail, that's where I was, and that's the scene I saw." And that's very important, that connection to the viewer.

I'm very excited about this series. You'll find them on **my website**, scattered around in different states.

I'd like to finish by asking: if someone came up to you and said they would like to get into painting panoramas like this, what advice would you give them?

I guess what I would do is kinda what I'm doing with the Great American Landscape project; I would take on a project and use it to promote my availability. What material I haven't flown, I would go on the Internet and see what comes up. From that material, I'd go ahead and put together what you felt would be the best view, if not as a map, then as a portrait.

Thank you so much, this was a great conversation to have.

Oh yeah, you bet. I've enjoyed it.

Crater Lake

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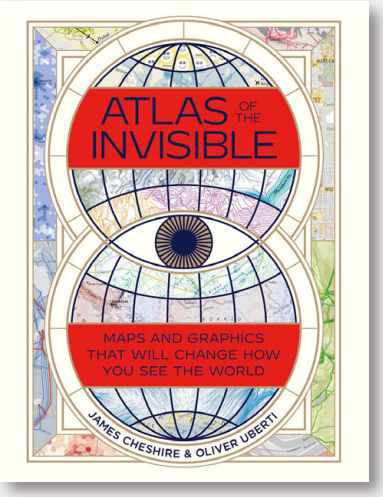

ATLAS OF THE INVISIBLE

By James Cheshire and Oliver Uberti

W. W. Norton & Company, 2021

216 pages, 63 maps and graphics

Hardcover: $40.00, ISBN 978-0-393-65151-5

Review by: Rosemary P. Wardley, National Geographic

Atlas of the Invisible is the latest publication from James Cheshire and Oliver Uberti, who have previously collaborated on atlases focused on the city of London and on animal migration. Despite its mysterious title, *Atlas of the Invisible* is typical, in both its layout and content, to other contemporary collections of maps and graphics. There are more than sixty maps and graphics on various topics spread throughout the atlas, each with a distinctive style, scale, and approach to subject matter. The individual topics are collected into four, loosely thematic sections: "Where We've Been," "Who We Are," "How We're Doing," and "What We Face." These are combined with an introduction, an epilogue, and an additional technical section.

In their "Preface," the authors recount the impact of the COVID-19 pandemic on both their professional and personal lives and, in doing so, set the tone for the entire book. Over two years of pandemic monitoring have shown the increasing importance of maps and graphics, and led to an onslaught of statistical data. Like many of us, the authors initially viewed this as a teaching opportunity. Cheshire—a Professor of Geographic Information and Cartography at University College London—writes of assigning his cartography students an exercise to map the growing case counts early in the pandemic, while the threat still seemed abstract and distant. However, as the months rolled on, and these maps, graphics, and visualizations of the COVID-19 situation brought home the scale and seriousness of the looming danger, they also helped clarify the purpose for *Atlas of the Invisible*: "today, we need graphics to reveal the invisible patterns that shape our lives" (13).

What are these "invisible patterns"? It is stated in the "Introduction" that: "sometimes we miss what we can't step back to see. Sometimes the invisible only appears with the creep of time. And sometimes, in the case of historical events, the visible becomes invisible with the loss of a generation" (17), so it seems that Cheshire and Uberti see visibility as a function of context, and particularly as understandable context. They illustrate this with a brief history of cartography and data visualization, and of the scientists who, they maintain, first made invisible data visible. Most *CP* readers won't be surprised to see well known examples from Alexander von Humboldt, Florence Nightingale, and John Snow referenced, but there are also lesser known histories shared, such as the SYMAP system, a precursor to our current GIS software. To learn about a rudimentary tool that was developed fewer than 50 years ago really helps to put into perspective how far this field has grown in such a short time! The authors finish up the "Introduction" with more modern examples of the trials and tribulations that come with visualizing big data, and with a short "How to Use this Book" section.

Each of the book's four sections consists of an introductory essay, followed by full-page maps or graphics, with every entry accompanied by a brief commentary from the authors. The first of these sections, "Where We've Been," aims to "challenge the stories we've been told about our

past" (32) by utilizing the wealth of digitized historical data that we now have at our disposal. Even just one single primary source, shipping logs, enables the authors to generate maps about the slave trade, the whaling industry, and changes in global shipping patterns over time. While these maps are built on concrete data, other visualizations in this section are more speculative in nature—for example, the attempt to map the areas once occupied by various Aboriginal peoples of Australia (42). The very idea of mapping a space of ownership is quite foreign to the way the indigenous peoples themselves understood their relationship to the landscape—so much so that it renders the application of ownership boundaries to a map extremely problematic. Another map in this chapter visualizes some of the most personal data any reader has, the origin and ubiquity of their last names by country (54).

Section two, "Who We Are," focuses on telling stories about people and societies through new lenses, and the authors assemble an impressive array of graphics to illustrate their points. Societal patterns that could once only be gleaned from extensive censuses or research studies can now be pulled from data from mobile phones and satellites. Among the most arresting of the maps shown are those that generate new, imagined state borders based on drivers' commute hubs and routes. Another illustrates underwater fiber-optic cables—physical lines that carry the internet and which, in turn, literally connect us all (or at least the two-thirds of the population with internet access!). I found this example most interesting as I reviewed it soon after the eruption of the Hunga Tonga–Hunga Ha'apai volcano snapped Tonga's lone undersea cable! The thin lines stretching across the map really put the fragility of those connections into perspective!

Section three, "How We're Doing," provides examples of how maps and graphics can be used as tools to shed light on truth and democratize the power that a map can hold. The introductory essay references the wrongs many past cartographers dealt out at the stroke of a pen: dividing Africa into colonial territories and redlining neighborhoods along racial lines, each decision leading to decades of inequality. But today some of those wrongs can be undone by taking a closer look at *who* is doing the mapmaking and for *what* purpose. Analysis of declassified bombing target maps from the Vietnam War has helped humanitarian groups locate unexploded ordinance (and perhaps help us to rethink the weapons of war we use today). Similarly, a graphic comparing hours of both paid and unpaid work by gender succinctly displays just how unequal the workload truly is!

Section four, "What We Face," contains visualizations focused on data about our changing planet. This section's introduction proclaims that "data has always had doubters and deniers" (156), and discusses how early meteorological forecasting faced much the same incredulity that climate change forecasting faces today. In this section you will find maps on topics that have become familiar in this age of climate change—such as the global extent of active wildfires and the increasing speed of glacial melt—but you'll also see innovative new designs, such as a calendar forecasting heat stress risk for every hajj over the next century shaped in the form of an intricate Islamic flower. The most impactful graph, though, comes from utilizing the classic population pyramid. A comparison of population pyramids for the years 2020 and 2100 demonstrates just how dramatically the global population is projected to shift in this century. The stark contrast between the familiar 2020 pyramid and the oblong shape of the 2100 projection—when longer lifespans stretch the top of the figure—reinforces the image of a looming future.

This *Atlas* is designed, according to the book's subtitle, to contain "maps and graphics that will change how you see the world." While that is quite a lofty goal, it is one I believe they live up to. With Uberti's background as an artist and Chesire's as an academic, the pair provide a good combination of unique visualizations explained in straightforward, fact-based terms. I was personally delighted to see many open-source datasets I had thought about mapping myself—such as Native Land Digital (native-land.ca) — displayed in new and interesting formats. I was also, when first skimming the pages, surprised to see so much text in an atlas, but the introductory essays were so entertaining and easily digestible that the free-flowing text ended up being one of my favorite parts of the book. The essays not only helped to give structure to the rather abstruse titling of the sections, but I found some interesting and useful historical facts woven in. The atlas is well paced, with approximately ten maps or graphics in each section, along with one or two in-depth topics given a gatefold or two-page spread treatment. While those of us immersed in the field of cartography and visual graphics might see a couple of familiar visualizations that are often found on "best of" lists, there are just as many that were unfamiliar to me.

As a cartographer who has been creating atlases for over fifteen years, I was delighted and thrilled with this new offering from Cheshire and Uberti. *Atlas of the Invisible* gives a refreshing look at some common datasets—for example, global temperature anomalies over the past century—while also presenting new or lesser-known data in insightful ways, such as street vulnerability to ice being used as a proxy for where to salt roads. One thing I found most useful were the thumbnails of each visualization that feature in the table of contents. Listing the maps by title and topic is useful, but I find that many times my strongest recollection is of how the map looked, and the little pictures give just the right prompt for recognition.

The *Atlas of the Invisible* offers ample inspiration in design, layout, color, style, and theme, and I believe that people from many fields will find it a useful and inspiring addition to their collection. Altogether, the *Atlas of the Invisible* is a handy book to have on your shelf.

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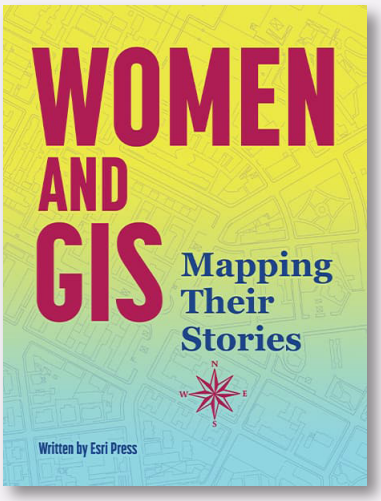

WOMEN AND GIS: MAPPING THEIR STORIES

By Esri Press

Esri Press, 2019

215 pages.

Hardcover: $14.99, ISBN 978-1-58948-528-0

Review by: R. C. Ramsey (she/her)

Each chapter of *Women and GIS* focuses on a different woman—outlining her personal journey from early childhood, through her education and entry into the professional world, and how she found herself working in the field of GIS. Throughout the twenty-three chapters, the reader is wafted along on a whirlwind, world spanning tour of education programs (some completed, some not), jobs (some fulfilling, some not), career paths, and projects (ranging from the early 2000s through 2018) that the spotlighted woman found pertinent on her path to and within GIS. The careers run the gamut—touching on GIS in academia, education, government, humanitarian agencies, nonprofits, exploration, conservation, and industry. The term *diverse perspectives* does not even come close to describing this book.

Pull quotes and words of wisdom from each woman are—despite being emphasized in large, often bold, and (usually) colored type—seamlessly interwoven into and between their varied and various stories. Color photographs and examples of a few of the maps and images produced by each woman give the reader a taste of their passions and of the worlds they have built around themselves. The individual chapters are brief: averaging eight pages each. Their abbreviated length makes for an effortless read that can be taken in large chunks or broken up across multiple evenings.

Journalists frequently report on gender disparity amongst students in science, technology, engineering, and mathematics (STEM) courses, and the corresponding domination of these professional fields by men. Esri is no stranger to these concerns, as was made apparent in 2022, when they **agreed to pay $2.3 million** to resolve a Department of Labor allegation of pay discrimination for 176 female engineers in 2017. When tech companies are confronted about their plans for closing this gap, many respond with public relations statements boasting statistics about the number of women on their payrolls. Unfortunately, head counts alone do little to bring more candidates to the fields, or staff to the firms. What does raise participation in a field is *showing* members of the targeted demographic performing in it successfully.

Showing success is the challenge Esri Press took on in 2019 with *Women and GIS: Mapping Their Stories*. It is the first in a series that has now grown to three volumes, including: *Women and GIS, Volume 2: Stars of Spatial Science* (2020) and *Women and GIS, Volume 3: Champions of a Sustainable World* (2021). Kudos to them for not simply splashing images of women in GIS on posters and pasting them up in schools, but instead taking a page out of the feminist geography handbook by reaching out to the persons involved to obtain qualitative, on-the-ground conversations that put names and accomplishments to faces. Showing real examples of women as active and leading participants in GIS makes it easier for other women to envision themselves in this field.

Women and GIS: Mapping Their Stories introduces the world to twenty-three powerful, motivated, and driven women in the GIS technology field. Each woman's passions and

interests are highlighted—demonstrating that they didn't come to the field just for the science and art of GIS; they came because it supported them and facilitated their work in pursuit of their interests. The variety of individual stories allows readers—even those readers who may not, at this point, be entirely sure what GIS is—to see how GIS could be used to further satisfy their curiosity about their own passions, and possibly encourage them to seek out this profession that they mightn't have otherwise considered.

As the book makes clear, there is no single mold or "type" to which women entering the field must conform in order to be successful, and, in fact, each chapter showcases the way that the backgrounds, education, and interests of the women discussed are both multifaceted and diverse. No two are identical: each is a unique combination of languages spoken, country of origin, educational background, and profession. Most gratifyingly, this is accomplished without beating the reader over the head with adulatory hagiography, as so many other institutions do when trying to advertise their successes in diversity.

This book does have some shortcomings. In giving each individual equal "on-air" time while keeping the overall page count reasonably low, the fast paced biographies are painted with very broad strokes—each woman's life is condensed to between six and fourteen pages. This brief overview of each woman comes in a surprisingly uniform format, in contrast to the diverse content of the stories. The structure for each chapter—cover their childhood; review their education; touch on their past jobs; discuss their careers; and pay tribute to their mentors—came across as a little too formulaic a way to review each woman concisely. I would have preferred a longer book if it offered an opportunity for deeper portraits. If a longer book would not have been possible, I would have preferred longer writeups on each woman, even if this in turn meant fewer women were featured.

The book itself maintains an incredibly positive voice—it seems that whenever a failure appears in the woman's life, it is framed as showing that if a door closes somewhere, a window surely opens somewhere else. In my opinion this, too, was a missed opportunity. Too heavy a focus on positives and successes undermines the human dimension and sort of flattens out the portrait. No person is perfect, and neither is their life—despite what social media purports to show. Very few readers care to read about perfection that is impossible to obtain and out of their reach. One of the reasons we have the gender gap in the first place is the socially reinforced disincentive to envisioning oneself in a certain position because it seems that only the perfect can succeed. Each person then shoots themselves down before even attempting the challenge because they don't think they can attain the perfection necessary. People want and need to see the at times messy, honest, genuine, and real struggles. Through struggles a person can find connection with another with whom they can relate by striking a chord of resonance. If this book is indeed seeking to inspire the next generation of women GIS professionals, the details of failures and challenges overcome shouldn't be glossed over.

This is not to imply that the struggles of these women are not narrated in a relatable manner. A great example of what is possible when this is achieved successfully is in the chapter about Dr. Paulette Brown-Hinds (26), where she discusses the hurdle of having a child while in graduate school. As she sat for her master's degree exams—eight months pregnant, wondering if she could manage it all—she overheard her fellow students mocking her for being pregnant while in school. She also discusses navigating conversations with her colleagues who are also moms, and the sensitive work of not discussing their own choices as if those choices were a critique of the other person's decisions. It is inspiring to witness women overcoming these challenges so that the next generation may not see having a family as a roadblock to a STEM career. These are by no means the only challenges women face, but it is a prime example that relates on the level of the next generation of women GIS professionals.

This book is an inspiration to women professionals either currently in GIS or considering it as a part of their career path. In fact, in this regard every word in *Women and GIS* is significant. It pulls back the curtain to reveal a number of women who have already brought their chair to the table, and it draws attention to a critical factor in how they got there: mentorship. This mentorship theme is a thread that runs through all the varied stories in this book. Each woman reached her goals or overcame a challenge with the mentorship and support they found in unexpected places. Building a network of support and mentoring requires time and effort, and the younger a person starts working on it, the better their chances become. As the chapter about Kate Chapman points out: "Many women enter STEM fields of study, and then leave mid-career. She says she wishes she had known earlier about

some of the frustrations women might face midcareer so she could have developed a better mentorship and support network for herself" (48). Here, again, is another instance where future professionals benefit directly from a frank discussion—with no sugar coating—of the challenges and frustrations that can be encountered, and how others have learned from them.

This book not only showcases how these women *became* GIS professionals, it reveals how they *stayed* GIS professionals. Books like this should exist for every career as a way for young professionals or curious teens to see the variety of jobs and paths related to that career. Despite what is often told to teens, there is rarely a single, straight path to any career goal. All too often youth are told to think inside the box and answer the questionnaire using only the multiple-choice options—and only too rarely are they offered the opportunity to conclude that there is more than one way to reach a goal. This book provides just that opportunity.

The photographs of the featured women, their work, and their world, ground the book in reality and are imperative to bringing home the theme that GIS can be an inclusive space for all. The quotations and words of advice scattered throughout the text could easily be plucked from the book, written on Post-its, and placed in prominent spots near one's computer monitor as a reminder or mantra for moving forward during difficult or tumultuous times. The words provide insights from women who have indeed been there and done that, reaching across space and time to encourage the next generation of women in GIS and STEM.

Women *do* exist in GIS, and it is certainly time we praise them for their contributions and their struggles. While *Women and GIS* might have benefited by staying a while longer with each woman, it does an admirable job introducing us to twenty-three diverse and admirable people in only 215 pages.

This book is a giant leap in the right direction. It is a fantastic, gripping book for inspiring a young professional woman in GIS and I look forward to the deeper dives with women in the GIS field that will inevitably result from its existence.

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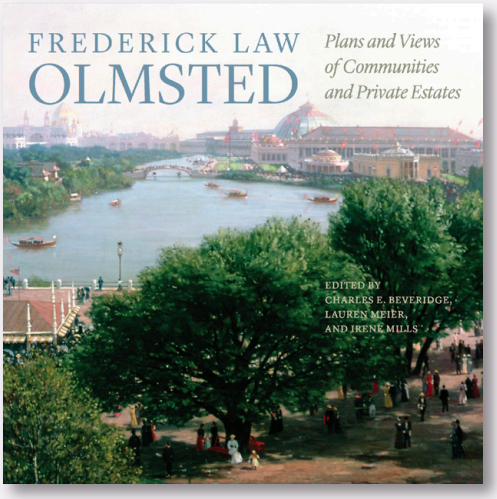

FREDERICK LAW OLMSTED: PLANS AND VIEWS OF COMMUNITIES AND PRIVATE ESTATES

Edited by Charles E. Beveridge, Lauren Meier, and Irene Mills

Johns Hopkins University Press, 2020

596 pages, over 500 images

Hardcover: $74.95, ISBN 978-1-4214-3867-2

Review by: Nat Case (he/him), INCase, LLC

A REFERENCE VOLUME that will presumably never be duplicated, *Frederick Law Olmsted*: *Plans and Views of Communities and Private Estates* should be recognized as essential reading for those whose interests include American landscape architecture. It is the most recently published part of a comprehensive, multi-volume collection of the writings and works of the man who, for all practical purposes, established landscape architecture as a serious intellectual field. This volume contains plans for seventy non-park projects that Olmsted either designed himself or had an authorial hand in. Landmark campuses like those of Stanford University and the University of California; public spaces like the National Zoo; private estates, exemplified by the 195 square mile (510 square kilometer) Biltmore Estate in North Carolina; and pioneering planned communities like Riverside, Illinois, are all included. Other volumes in the series collect plans, views, and writings on Olmsted's many other projects.

The superb print quality and the generous eleven-by-eleven-inch pages give ample room to see the shape of Olmsted's vision. The high quality of the reproductions means that even though they are nearly all substantially reduced in size, the reader still can still get an excellent sense of their texture and graphic quality. As a cartographer, I was sorry not to see more detail, or any discussion of the plans as graphic works, but this is consistent with the editorial direction of the book, directing our attention to the ideas the plans embody, and the intellectual thrust that the works represent. The plans Olmsted drew for any particular project were the means to an end, tools to both create both the physical spaces and enact his humane vision of humans in those spaces, rather than artworks in themselves. This book keeps its focus on those ends and on the processes Olmsted used to reach them, whether they were ultimately realized or not. The text, though generally brief, gives attention to his ongoing negotiations amongst his own visions, the vision of his fellow designers, wishes of his clients, and conditions on the ground revealed during construction.

Most of the projects in this volume are illustrated with multiple images. Original plans are often accompanied by photographs, of both freshly-planted landscapes and of later conditions with more mature growth. This allows the reader to better understand the three-dimensional spaces Olmsted was envisioning: a landscape vision that was meant to be experienced by walking *through* the landscape rather than being picturesque, viewed from a particular set of vantage points. Because of this, the typical plans for his landscape designs are misleadingly two-dimensional. He also sometimes used drawn views as tools to play with the spaces in his mind's eye, and to communicate his conceptions to both clients and to the construction teams. The working diagrams are specific in the ways a construction crew would need—plant this species here, regrade the land there to this measurement, build a stone wall just so—and the views are a necessary part of communication to the client and to others on the team, as the visual impression of the landscape design is its essential point. It is in the sketches, though, that the integration of the often sizable elements from other hands is negotiated: showing how,

say, a very large house is made to look to be an organic part of the landscape. It is also interesting to see how, in many cases, he entirely cedes to the architects working on the buildings themselves the realization of their own visions, simply putting a placeholder "building here" marker on the plan. Perhaps this relationship of simultaneously standing up for his own design autonomy and vision while seeking to be collaborative with presumably strong-willed building architect colleagues plays out more explicitly in the text portion of his papers, but you can see hints of it in the interpretive texts in this volume discussing some of his large projects, where the relationship between buildings and grounds is more complex.

One thing that is simply taken for granted in the text, and in his work, is the social and economic class of his clientele. While his artistic vision was universal in scope and his moral vision throughout his career was vigorously egalitarian, in practice his clients were some of the wealthiest men of his time. Unlike his work on urban parks—which in his vision needed to be open to the general public, an idea he defended with great energy over his career—he never really worked on housing for a modern, working-class audience. This reality can cast suspicion on, for example, the motives behind some of the social engineering aspects of his residential developments. His one "village" plan, for the town built to support George Vanderbilt's vast Biltmore estate, is a throwback: a feudal village adjacent to the great castle on the hill. His forays into town planning were suburbs meant for an upper-middle-class clientele, with Riverside, Illinois being the most prominent example. He often expressed a desire for more green space, and for views that changed as you walked down the street—foreshadowing much of modern suburban design—but most of his work was not embedded in the harsh realities of housing for the droves of immigrants and freed slaves who found themselves in the sort of horrific living conditions Jacob Riis documented in *How the Other Half Lives* in 1890. Olmsted decried those conditions—and his parks were meant as capsules of natural beauty and peace created for the relief of city-dwellers—but actual working-class living conditions were not, ultimately, within his professional purview.

One theme running through this book, and Olmsted's work in general, is the importance of paying close attention to the nature (in multiple senses) of the place itself, as it existed before landscaping and as it existed in a Platonic ideal in Olmsted's mind, rather than simply imposing the owners' desires and needs on the land. The book's text makes this point repeatedly and it is best illustrated by Olmsted's final great project, the design of the grounds at Biltmore. Olmsted wanted Biltmore to be a global showplace for his ideas, and the book takes sixty-five pages to work its way through them: they include a model of modern managed forestry (where the first dedicated forestry school in the United States was founded), an arboretum with a comprehensive specimen collection, and grand vistas of and from the house itself (still the largest private residence in the nation). Olmsted found much of the land there overworked and depleted, and his vision of restoration, while it does not entirely coincide with today's ecological sensibilities, was in contrast to the visions of landscape he found himself arguing against, involving heavily artificial gardens and intensive use of the land without much regard to its underlying health. On one hand, he was interested in creating a visual effect appropriate to the specific context, but on the other, he was aware of, and interested in, the long-term effect his ideas and example would have in the world. It is a striking and subtle combination which you can see played out in a variety of ways over his career, even in this subset of "other projects" besides the urban parks for which he is best known.

This volume is meant to stand alongside Olmsted's collected papers and the other supplementary volumes showing his work. As a single part of a series, it sometimes seems to miss, or take for granted, information that is presumably available in its companion works. For example, while it references discussions Olmsted had with clients and colleagues, it doesn't feel the need to spell those out in detail. So, while I would recommend *Frederick Law Olmsted: Plans and Views of Communities and Private Estates* as a worthwhile purchase by itself, I would also recommend libraries consider purchasing the full series to give readers a more comprehensive picture of the Olmsted's works and ideas.

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Robinson, Arthur H., Joel L. Morrison, Phillip C. Muehrcke, A. Jon Kimerling, and Stephen C. Guptill. 1995. *Elements of Cartography, 6th Edition*. New York: John Wiley & Sons.

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Peterson, Michael. 2008. "Choropleth Google Maps." *Cartographic Perspectives* 60: 80–83. http://doi.org/10.14714/CP60.237.

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Danzer, Gerald. 1990. "Bird's-Eye Views of Towns and Cities." In *From Sea Charts to Satellite Images: Interpreting North American History through Maps*, edited by David Buisseret, 143–163. Chicago: University of Chicago Press.

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