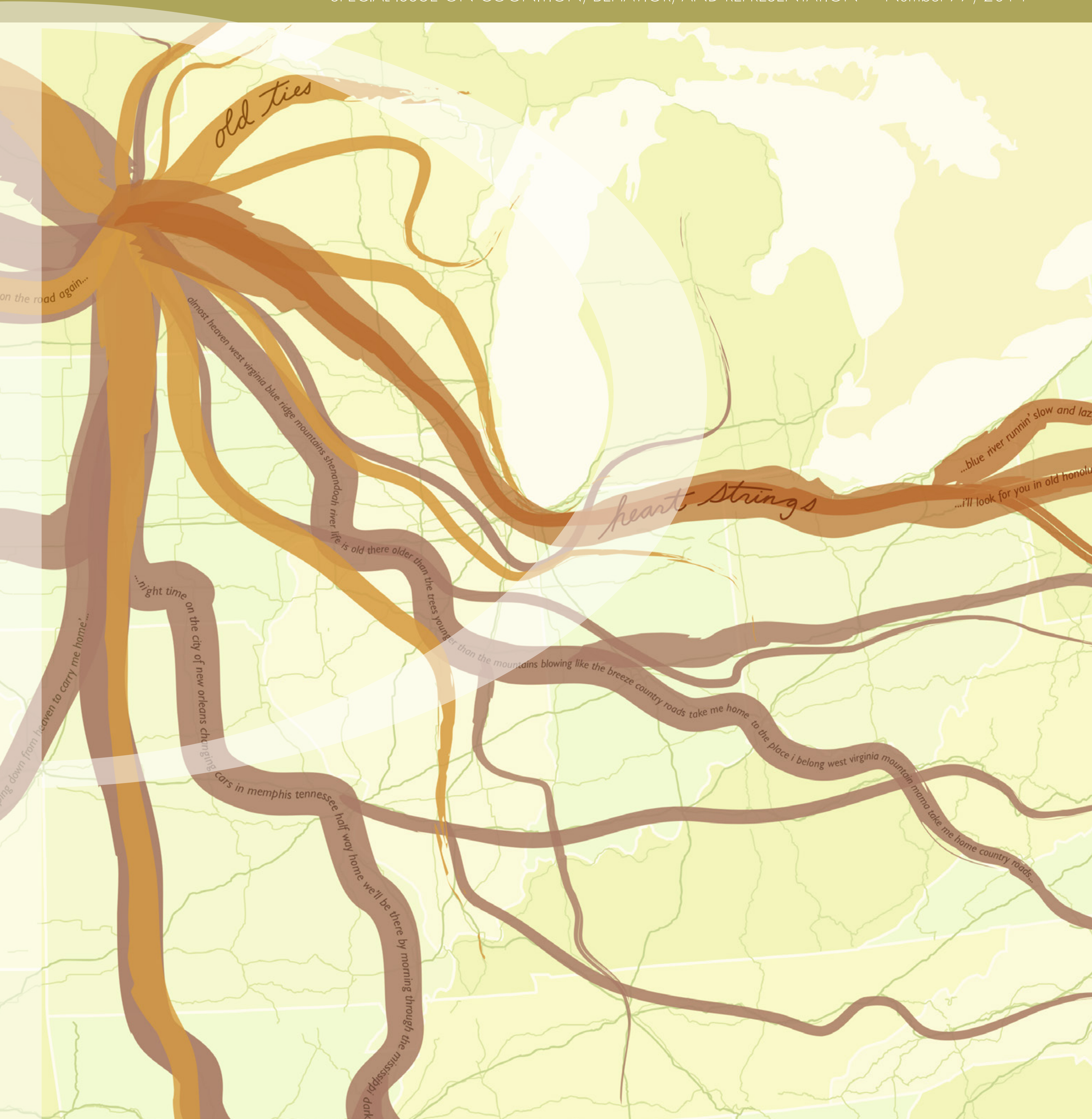
Cartographic Perspectives

The Journal of **nacis**

SPECIAL ISSUE ON COGNITION, BEHAVIOR, AND REPRESENTATION Number 77, 2014



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IN THIS ISSUE

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ABOUT THE COVER: *Color-adjusted detail from the Memory Roots, by Brita Swanson. See page 5 for full image in original colors.*

LETTER FROM THE GUEST EDITORS

Thanks to its exceptional leadership and an engaged membership, NACIS has assumed an active role in building connections across otherwise segmented cartographic communities. NACIS cultivates and integrates perspectives on cartographic design from industry, government, and higher education, which enables the productive exchange of ideas across these sectors. It connects students with employers, simultaneously building individual careers and the collective cartographic workforce. In its mapgiving activities, NACIS brings maps to people who do not always have the opportunity to engage with them. Finally, through initiatives like the *Atlas of Design* and *CartoTalk*, NACIS has helped to shape the global cartographic conversation.

It is in the NACIS spirit of bridge building that we offer this special issue of *Cartographic Perspectives*. The issue presents a veritable "who's who" of cartographic acronyms, and is a direct collaboration of NACIS (through its publication, *CP*), the International Cartographic Association (ICA), and the Cartography Special Group of the Association of American Geographers (AAG). The ICA promotes the scholarship and professional practice of cartography in an international context, with a congress of over seventy-five member nations convening biennially at an international destination. While the 2015 conference will be held in Rio de Janiero, Brazil, the 2017 meeting will be held in Washington, DC (the first ICA conference in the US since 1978!). It will be important to gather support from the NACIS community as that event approaches. The Cartography Specialty Group of the AAG, while much smaller is size and scope, promotes the scholarship and professional practice of cartography within the broader geography community, and is charged with organizing sessions on and competitions in cartography during the AAG annual meeting.

This special issue had its genesis in the form of four sessions focused on the topics of Cognition, Behavior, and Representation at the 2014 AAG Annual Meeting in Tampa, Florida. The sessions were organized jointly by the AAG Cartography Specialty Group and three ICA Commissions: the Commission on Cognitive Visualization (represented by Amy Griffin and Sara Fabrikant), the Commission on Geovisualization (represented by Anthony Robinson), and the Commission on Use and User Issues (represented by Robert Roth). For NACIS members looking forward to the 2017 ICA conference, it is important to note that there are twenty-five ICA Commissions active today. Several of these ICA Commissions actively collaborate with NACIS already, including the ICA Commissions on Mountain Cartography (see ***CP 67***) and Map Design (see ***CP 73***).

A total of twenty abstracts were presented as part of these jointly organized AAG sessions last April, resulting in a healthy discussion on the topics of cognition, behavior, and representation, which we happily extended beyond the paper sessions and into the evening over drinks. We then invited the presenters to expand their presentations into full papers for consideration in *Cartographic Perspectives*, with the goal of highlighting emerging trends in cartographic research and extending the reach of the discussion beyond the conference presentations themselves. Following peer review, four research papers were accepted for this special issue. Before introducing each paper, we'd like to thank the contributors to the AAG sessions and the numerous individuals who volunteered their time as reviewers. In total, cartographers from eleven countries participated in the special issue in some way (Australia, Belgium, Canada, China, the Czech Republic, Germany, the Netherlands, Sweden, Switzerland, the United Arab Emirates, and the United States of America)—an indication of the reach that such collaborations offer.

Our first paper approaches the central theme of the recent 2014 NACIS conference: cartography and time. Menno-Jan Kraak (Vice President of the ICA), Barend Köbben, and Yanlin Tong of the University of Twente in the Netherlands provide a systematic review of methods for representing movement, such as timelines, flow maps, linear cartograms, and the space-time cube. They argue that an integrated approach that coordinates multiple representations offers the best pathway to understanding movements in space and time. The paper is packed with useful illustrations for representing movement on maps and timelines, and includes source code for implementing several of the examples in D3 (a resource that will be of use to professionals as well as scholars). Menno-Jan, Barend, and Yanlin also are the first contributors to *CP* to discuss and implement eye-tracking, an evaluation technique praised in other cartographic outlets for its ability to study the impact of map design on cognition.

In the second paper, David Retchless of Penn State discusses the conceptualization and representation of uncertainty on map-based visualizations of global sea level rise. David introduces and synthesizes current perspectives on uncertainty representation in the disciplines of Cartography and GIScience, and appends to these perspectives emerging ideas on uncertainty representation in the cognitive and decision sciences. David then uses this foundation to discuss how individual differences on risk perception and response impact decisions regarding risk and resiliency. The paper closes with helpful recommendations for cartographers when designing maps of uncertain future sea levels, many of which translate to other, potentially deleterious impacts of climate change. In doing so, David reminds that cartographers and maps have an important role to play in addressing impending, global-scale problems.

Next, Thomas Pingel (President of the AAG Cartography Special Group) of Northern Illinois University and Victor Schinazi of the Swiss Federal Institute of Technology in Zürich evaluate the relationship between the size of a navigable space and the strategies that people use to search for objects in such space. This work highlights the importance of studying spatial cognition and wayfinding behavior within cartography, as it is essential for cartographers to understand how people conceptualize and utilize the places we ultimately represent in our maps. Through an empirical study, Tom and Victor reveal that individuals tend to adopt a more systematic search pattern as the size of the space they need to navigate increases. Their results suggest ways in which we might use this knowledge of human spatial cognition to inform how we design maps that support navigation.

The peer-reviewed content of this special issue concludes with a paper from Ian Muehlenhaus of James Madison University (and Past President of the AAG Cartography Special Group). Ian explores the potential intersections between film theory and cartography, adapting approaches from film studies to interrogate map designs. To this end, Ian argues that traditional map evaluation too often is focused on the content of the representation, rather than the overall form of the representation. Ian goes on to demonstrate how maps can be evaluated in terms of their form, eloquence, and meaning, and proposes that film theory can be used to reshape the ways in which cartographers conceptualize map evaluation and critique. Ian's paper builds on his recent presentations in NACIS sessions on map design, and illustrates the overlapping interests of NACIS, the ICA, and the AAG Cartography Specialty Group.

NACIS, the ICA, and the AAG Cartography Specialty Group have highly compatible aims. It is our hope with this special issue to continue bridging gaps across these cartographic communities, especially given the recent United Nations resolution in support of the International Map Year in 2015–2016, and the upcoming 2017 ICA meeting in Washington, DC. These activities represent excellent opportunities for NACIS members to highlight their academic and professional excellence in an international forum. We are excited to share the NACIS way with cartographers from across the globe, and hope you join us in Rio, DC, and beyond to celebrate all that cartography has to offer.

Anthony C. Robinson and Robert E. Roth

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Integrated Time and Distance Line Cartogram: a Schematic Approach to Understand the Narrative of Movements

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To understand the nature of movement data, we introduce an alternative visual representation looking at paths from different perspectives. The movements and their stops are schematized into lines. These are distorted based on time or distance by applying line cartogram principles to answer specific location- or time-based questions. A prototype consisting of multiple linked views, including the line cartograms and a map, is implemented in a web environment using D3.js. It allows one to explore the nature of single or multiple movements. The option to compare multiple movements gives the solution its unique character. A preliminary evaluation of the product shows it is able the answer questions related to time and space accordingly.

KEYWORDS: movement data; timeline cartogram; distance line cartogram; schematized map; flow map; D3

INTRODUCTION

The availability of movement data is overwhelming, and sophisticated analytical and visualization tools are required to understand the nature of the movements and to discover, understand, and explain patterns in space and time (Andrienko et al. 2013). Extensive study programs that look at data from multiple perspectives have been executed (move-cost.info), and many different visual representations are available for displaying movements (www.visualcomplexity.com). The nature of the movement data will determine which representation is most suitable.

Most visual representations contain the path of movement and its direction, as well as qualitative and/or quantitative information. Examples are the flow map, the network map, and the space-time cube. Each of these examples has characteristics which support particular questions. The flow map is useful for showing attribute values in space (Tobler 1987), while the space-time cube, as the name implies, can deal with questions related to time and space (Hägerstrand 1970; Andrienko & Andrienko 2010).

No single map is suitable to answer all questions related to space, time, and attributes. In addition, all can suffer from clutter and overplotting. The former occurs when there is an uneven spatial and temporal data distribution, and the latter in situations where the amount of data to display is large. These problems can only (partly) be solved if one combines analytical methods such as clustering and filtering with highly interactive visualizations (Keim et al. 2010).

The use of multiple and different visual representations in an interactive linked view environment can reveal patterns otherwise missed (Dykes, MacEachren, & Kraak 2005; Roberts 2005). In this paper, we suggest combining several cartographic representations—the timeline, the cartogram, the schematic map, and the flow map—to allow a better understanding of movement data. The result is an integrated linear time and distance cartogram. It does not solve the problem of large data sets, but it does solve some of the clutter and overplotting problems found in other graphic representations, like the space-time cube, and it does provide an alternative and insightful way of looking at movement data. Figure 1 shows examples of the four graphic representations that we will combine for a better understanding of movement data.

The *timeline* example in Figure 1a displays three reorganizations of the municipalities in the province of Overijssel, in the Netherlands. Timelines place events in a chronological order. They are mostly used for linear time, but variations exist for cyclic events, such as the seasons. Timelines can be used to answer temporal questions easily: when (*instant*), how long (*interval*), etc. The history of timelines in graphics can be found in Rosenberg and Grafton (2010). Kraak (2005) describes the timelines from a cartographic perspective, while Silva and Catarci (2002) do so from an information visualization viewpoint.

In a *cartogram*, geographic space is replaced by attribute or time space. The size of a geographic unit no longer represents square kilometers, but instead, for instance, shows the number of inhabitants or the production of corn (Tobler 2004). Alternatively, geographic distances are replaced by travel time (Shimizu & Inoue 2009). Figure 1b shows an example of such a cartogram depicting travel time by train from the Dutch city of Gramsbergen (Ullah & Kraak 2014). Cartograms answer questions in relation to the attribute or temporal distribution of the topic. However, this only works if the user can mentally link the image to the real geography.

Schematic maps simplify reality to emphasize selected aspects of geography via an extreme application of generalization and a fixed design style (Avelar & Hurni 2006; Cabello, de Berg, & van Kreveld 2005). For example, a schematic map might use only vertical, diagonal, and horizontal lines while following a particular set of colors and fonts. Figure 1c shows a detail of one of the most well-known examples of a schematic map, the London Underground map based on an original design by Harry Beck (Garland 1994). An "extreme" kind of schematic map is the so-called chorem, proposed by Brunet (1980) and described by Reimer (2010). Schematic maps give a

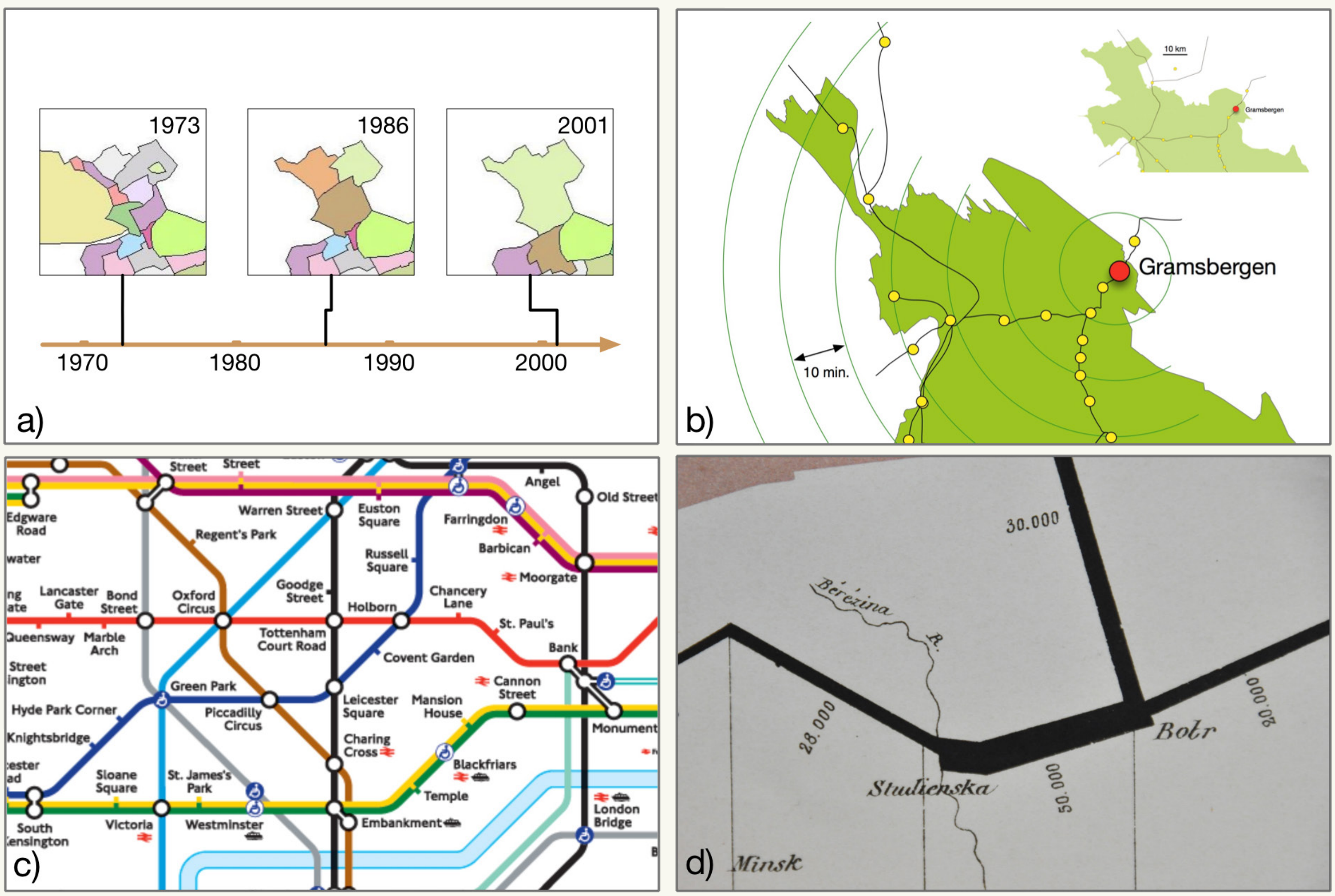

Figure 1: Graphic representations that we will combine include a) a timeline, b) a cartogram, c) a schematic map, and d) a flow map.

quick insight into the selected topic, and depending on the design, can answer generic questions about location, attribute, and time.

A *flow map* shows the path and volume of movement, such as the number of people or amount of goods transported. Location and attribute information can be clearly deduced from these maps. However, even though time is inherently incorporated, it is not always explicit (Johnson & Nelson 1998). Figure 1d shows a detail of Charles Joseph Minard's map of Napoleon's invasion of Russia, where the width of the line symbols represents the number of troops in Napoleon's army (Kraak 2014). A flow map can answer questions related to the *where*, the *what*, and often the *when* of movement.

THE INTEGRATED TIME AND DISTANCE LINE CARTOGRAM

Figure 2 explains the integration of these different cartographic representations. Basic data are paths (x, y, and time), such as a GPS-track, and stops located along those paths (Figure 2a). Stops are an essential element of the linked time and distance line cartogram. The distortions on the timeline or the distance line are defined in between stops. In some situations, these stops are given: for example, towns along the roads, bus stops, or control points during an orienteering race. In other situations, stops have to be derived from the path. In that case, GPS-tracks describing the path are the data source, and stops can be determined based on a spatial and temporal threshold (a defined range and minimum duration). Algorithmic solutions to this problem have been proposed by Palma et al. (2008) and Spaccapietra et al. (2008), among others.

In the schematization process, the track is transformed into a straight line, representing the total distance traveled. The stops are then added to their proper location on the line. In the next step (Figure 2b), a timeline—of the same length as the distance line—is plotted parallel to this distance line. The units on the timeline are in proportion to the total time traveled. In the Figure 2b example, the unit is one minute. On the timeline, the stop durations are separately coded and linked to the stop on the distance line. This figure gives a generic overview of the relation between time and distance, and shows that neither is equally distributed.

In Figures 2c and 2d, the relation between time and distance (i.e., geography) is further explored by distorting each individually. This is where the cartogram principle is applied, manipulating the distance line based on time and the timeline based on distance. In Figure 2c, the stops on the distance line are expanded based on the units they occupy on the timeline, such that the connecting lines are vertical. It now clearly shows the different stop durations.

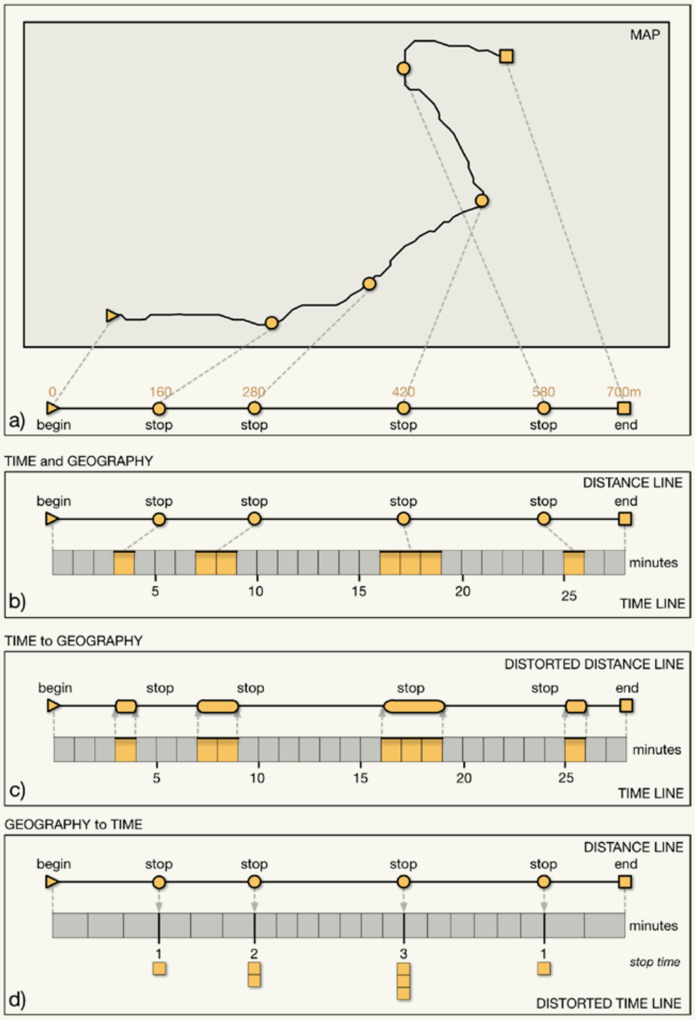

Figure 2: The principles of the integrated time and distance line cartogram include a) the schematization of the movement; b) the direct relation between the geography (distance line) and time (timeline); c) from time to geography—cartogram principles applied on the distance line; and d) from geography to time—cartogram principles applied on the timeline. On the distance line, the location of the stops are represented by the (deformed) orange circles. On the timeline, the orange boxes refer to the moments stopped.

In Figure 2d, the reverse happens. The stops are projected on the timeline and the stop-duration units are removed. The remaining time units are compressed or stretched between the stops. In the figure, this stretching is clearly visible between the last stop and the end. This graph gives an indication of the speed traveled on the separate section between stops. Note that between-stop speed is considered constant, even though this might not always be the case in reality. Wherever the time units are stretched out, the person moved faster, compared to segments with compressed units. To keep a notion of the stop duration, there are indicators below the timeline at the stop location. The example uses stacked squares, but one can imagine that when a stop is considerably long, another design is more appropriate, such as numeral text (see Figure 5c) or proportional symbols.

In Figure 2, only location and time are used. Our proposed solution also allows the integration of quantitative or qualitative attribute information. Figure 3 gives an example of this. Minard's map of Napoleon's Russian Campaign, displaying the path and amount of troops, has been partly schematized. Since the army moved mostly east to west and back again, the part of the path that returns west from Moskva (Moscow) has been flipped over to get a more or less horizontal distance line. To keep a visual link to Minard's original map, the path has not been fully straightened. The width of the path represents the amount of troops. The timeline has been cartogram-ized, resulting in a very compressed four weeks at the end of September and beginning of October when Napoleon stayed in Moskva (Figure 3a).

In Figure 3b, the distance line has been further schematized, resulting in a straight line. It has also been cartogram-ized, with the locations of the towns (in gray) moved to link with the dates on the timeline that the army actually visited those locations (in black). For instance, compare how far apart Moskva and Malojaroslavetz are in Figure 3a versus Figure 3b. In comparing these two figures, the attribute data have been swapped from the distance line to the timeline. The height of each time unit (here a single day) corresponds to the number of troops still participating in the campaign at that particular time. It would

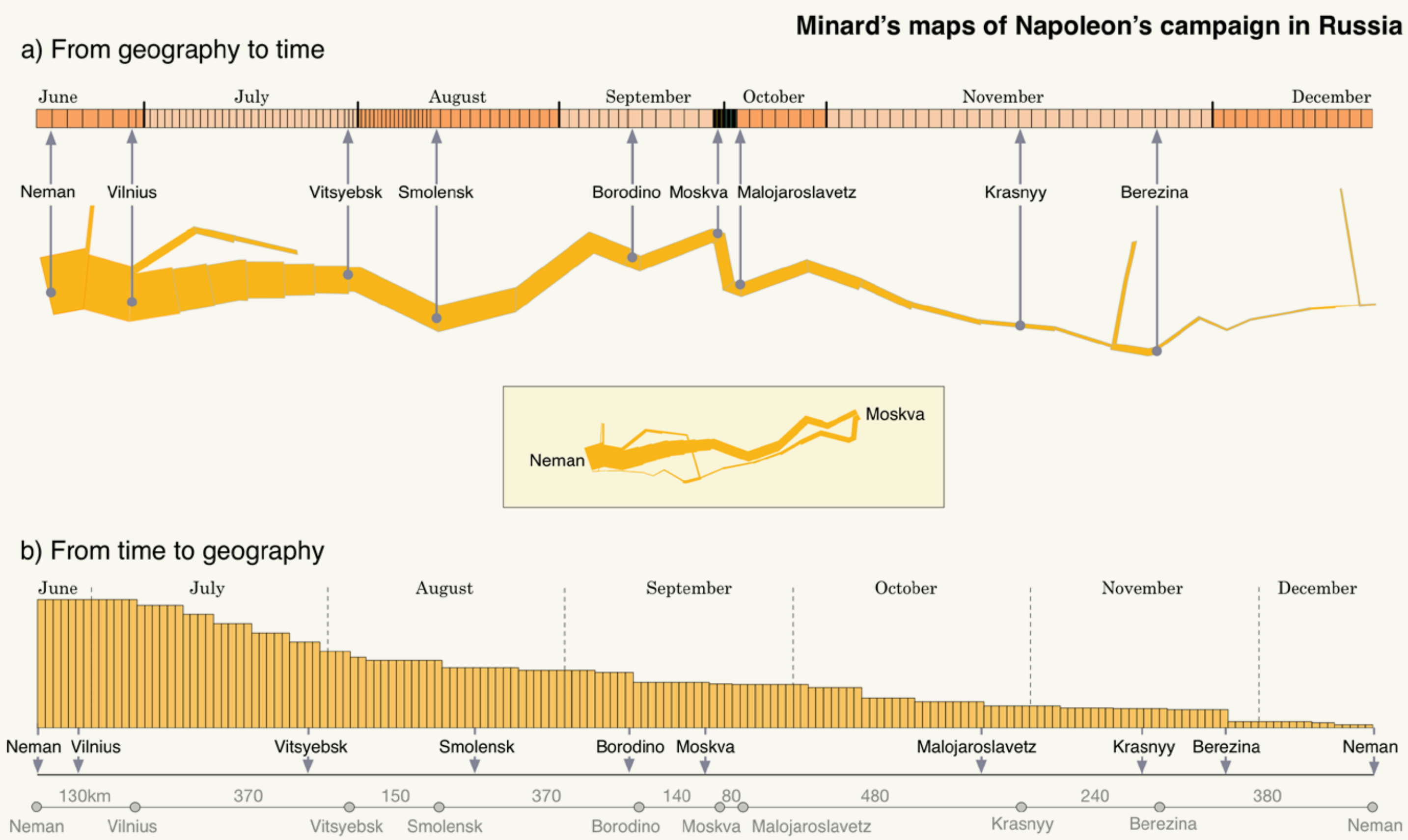

Figure 3: The time and distance lines extended with attribute information, converting a) from geography to time—the distance line is encoded with attribute information; and b) from time to geography—the timeline is encoded with attribute information (based on Kraak 2014).

be possible to add qualitative data too, by segmenting and coloring the bars based on the participating army corps.

Visualizing a single path, as in Figures 2 and 3, can be revealing, but in many situations the option to compare multiple paths will be more informative. As Figure 4 demonstrates, several combinations are possible. In the first four situations shown, the paths are all the same, but the location or order of the stops are different. Trains that stop everywhere, or buses that stop on request only, are typical examples. In the last four situations, the paths are not equal, and also the locations or order of the stops are different. Figures 5 and 6 provide more detailed examples of some of these situations.

Figure 5 explains the basic options when comparing two movements along the same path. In the example, a bus line in Minneapolis-St. Paul, USA is used. As the map shows, the line starts at Apple Valley and, via three potential stops, it ends at the Mall of America. Figure 5b has a timeline and two distorted distance lines of the green and red bus. The green bus leaves at 06:55 and makes a pair of two-minute stops, arriving at the Mall at 07:24. The red bus leaves Apple Valley at 07:02, makes three stops, two of two minutes and one of a single minute, and arrives at its destination at 7:35. In the lower diagram shown in Figure 5b, the timeline information has been normalized, with all trips starting at 00:00. This allows a better comparison of the red and green bus

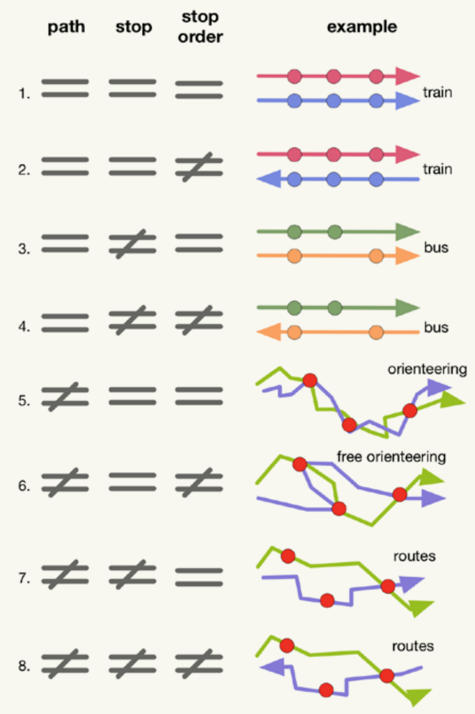

Figure 4: Comparing movements in time and space. Examples of eight different situations where path, stops, and stop order are varied.

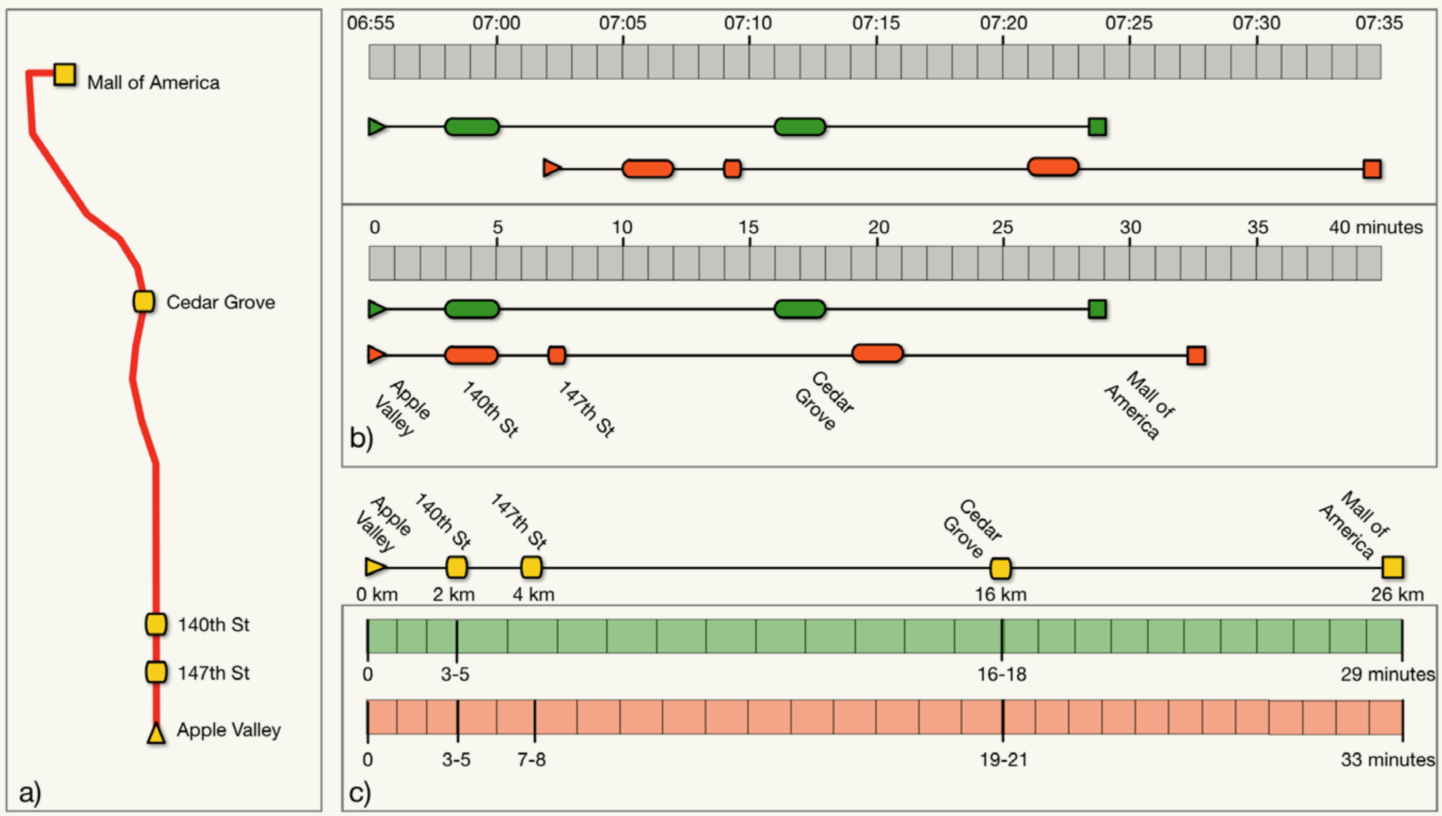

Figure 5: Comparing two bus trips, according to a) the route; b) the timeline and distorted distance lines as default and normalized; and c) the distance line and normalized distorted timelines.

when interested in the total trip length. The extra stop of one minute results in a longer trip duration. Other reasons could be involved, such as the bus encountering more traffic because it started later. For this kind of reasoning, the upper diagram is needed as well. In Figure 5c, the same information is displayed via a distance line and two distorted timelines. In the timelines, the time units (minutes) are distorted between the stops. The stops are indicated by vertical lines, and a text label indicates the stop times relative to the start of the trip. Compare this with the visualization of stops by stacked squares in Figure 2d. An online, interactive version of this kind of visualization compares three bus lines in the city of Dublin (see **kartoweb.itc.nl/kobben/D3tests/tracksViewer/busses.html**).

Figure 6 shows a snapshot of an interactive web application using integrated time and distance line cartograms. Background information on its development and implementation is given below. This example represents the fifth situation from Figure 4. The map shows part of the city of Dresden, Germany, with the paths of two runners who participated in the International Cartographic Conference 2013 Orienteering Race. Runners had to follow given control points in a fixed order, but due the different accuracies and settings of runners' GPS devices, it looks as if the control points are not always on the exact same positions.

The blue runner (Laszlo) is an experienced runner, but the red runner (Menno-Jan) was only competing in his third orienteering race ever. The map shows that the paths and strategies employed to reach the control points differ. The lines in the "time to geography" box present a timeline and two distorted distance lines. The third stop of the red runner is selected because it looks like a relatively long stop, and the pop-up menu in the map reveals it took just over a minute before the runner located the control point. It also gives the distance covered so far. The selected control point on the map is simultaneously highlighted on the line diagrams (by increasing the size of the symbols). The diagram also shows that, despite the delays, the red runner was faster. In contrast to Figure 5c, the "geography to time" box has been split into two diagrams. The distorted timelines show only a minimal distortion (compare the time units between the start and control point 2). The stop length is not shown below the timelines. Comparing these two diagrams shows that the red runner covers quite a bit more (unnecessary) distance. The blue runner was more efficient. The red runner also missed a control point (6) and therefore was disqualified.

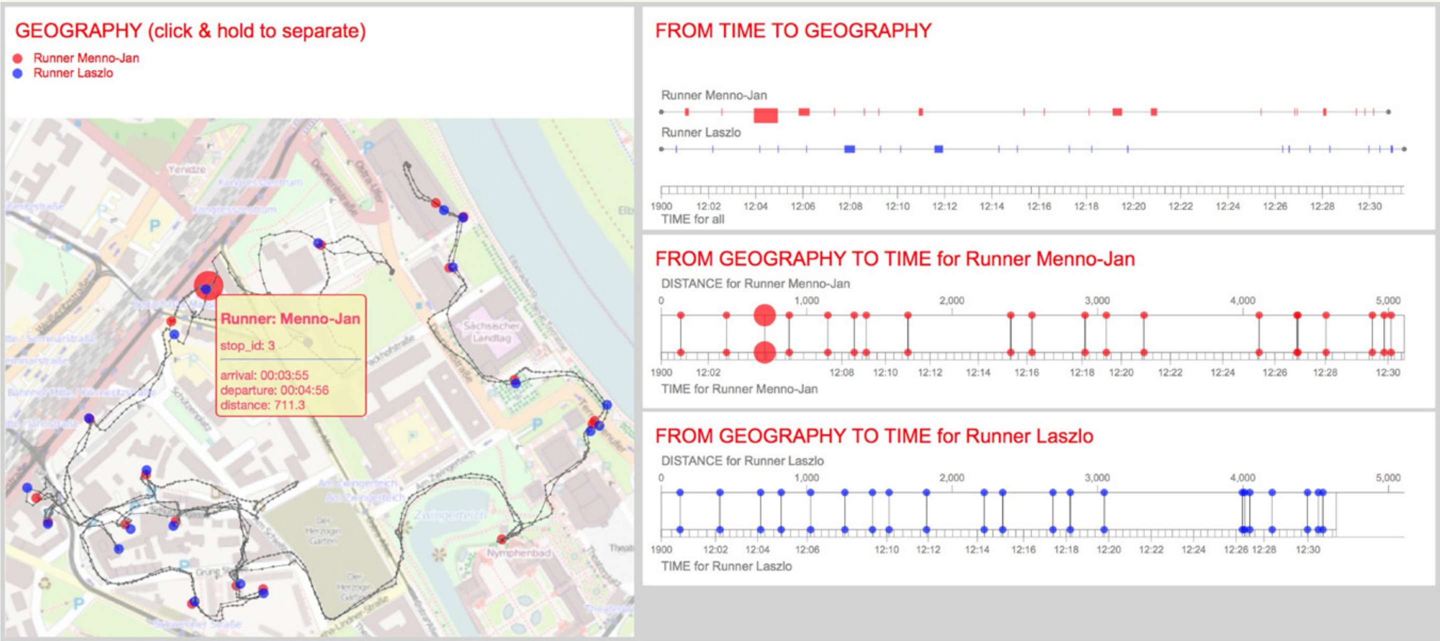

Figure 6: The web based implementation of the integrated timeline and distance line cartogram. The example shows the comparison of two paths in an orienteering race.

IMPLEMENTATION

To implement the visualization functionality of the integrated time and distance line cartogram described above, we looked for a solution that would offer an easy implementation of high-quality graphics in an interactive web environment. The selection was guided by the need to have viewer components based on the modern Open Web Platform, the range of advanced, open Web standards enabling the creation of standards-compliant web applications (**www.w3.org/wiki/Open_Web_Platform**). In practice, this boils down to an updated standard (HTML5) for encoding web pages, combined with standards for styling and layout (CSS3), and for vector graphics (SVG), as well as a scripting environment (JavaScript) to enable interactivity and business logic.

There are several JavaScript frameworks and libraries that support the Open Web Platform, and simplify the building of interactive web graphics using HTML5 in modern browsers. The D3 library (Bostock et al. 2011; **d3js.org**) was chosen because of earlier favorable experiences in using it in experiments with a client for thematic mapping of service-based data (Köbben 2013).

D3.js is a JavaScript library for manipulating web pages programmatically through their Document Object Model (DOM). It allows one to bind arbitrary data to the DOM and then apply data-driven transformations to it, using the full capabilities of modern web standards. D3 was found to be fast and efficient, even when using large datasets. Its code structure, based on the popular JavaScript framework jQuery, allows for dynamic behaviors of the objects, thus enabling maps with interaction and animation.

The resulting *TracksViewer* experiments are available online at **kartoweb.itc.nl/kobben/D3tests/tracksViewer**. Here, you can find the orienteering race example from Figure 6 as well as a version of the buses experiment from Figure 5, both of which show multiple events. Apart from these, versions with single events are also included; these show the possible timeline and distance line cartogram variations that were identified in Figure 2. To enable a better understanding of the relation between the various cartograms and the map, all the views in each of the visualizations are interlinked: whenever one moves the mouse over a stop event in any of the diagrams, the corresponding stop event is highlighted (by a change of the symbol size) in the other diagrams, and some key attributes of the data instance are shown.

All these visualizations use the same D3 code base (made available on the GitHub open source code-sharing platform: **github.com/kobben/D3tests/tree/master/tracksViewer**; also available at **cartographicperspectives.org/index.php/journal/issue/view/cp77**). The individual versions are created from a set-up file in which one defines the types of cartograms and maps to be shown, and the data attributes to use for the interlinking of the views and in the info panel. It also sets the map scale and center, as well as the time and distance scales for the line cartograms. These can vary substantially, as one can observe by the difference between the GPS walk visualization, covering 1500m in some 25 minutes, and that of Napoleon's Russian Campaign, which spans almost all of Europe's width over the period of half a year.

The data for the visualizations are stored as a GeoJSON, the spatially enabled version of the JavaScript Object Notation format. In principle, any GeoJSON file that stores a sequence of positions can be used. In the experiments, the data were originally GPS tracks, except the Napoleon data. The only pre-processing needed is to either identify the existing stops, or alternatively calculate or derive them from the tracks, as explained earlier.

We observed that in the examples with multiple events, the distinction between the individual tracks in the map could become quite difficult, most obviously in the buses visualization. Therefore we added the possibility to briefly separate the tracks when clicking and holding down the mouse button. Functionality for adding a background map was added, too, shown in the example in Figure 6. For now, one can only use a local raster file. But as the D3 library has full map projection capabilities, we plan to add the possibility of using Web Map Services.

PRELIMINARY EVALUATION

To get an idea of the usability of the integrated time and distance line cartograms, we conducted a small and preliminary test. Further testing is required, but some interesting insights were retrieved from this first evaluation. Table 1 shows the questions we formulated, related to time, distance, and space (map). The objective of the evaluation was to get an indication of the typical questions for which the proposed solution is suitable. The line cartograms were also compared with another visual solution able to show paths and stops, the space-time cube.

For the evaluation, two groups of eight Geoinformatics MSc students (n=16) were recruited. The first group had to answer the questions listed in Table 1 using the space-time cube, and the second group worked with the line cartograms to answer the same questions. A pilot test was conducted before the actual evaluation to improve the test set-up. The participants were first introduced to the purpose of the test, and given time to familiarize themselves with the testing environment. During the test, measures on effectiveness and efficiency were collected, by having participants fill out answer sheets, and think aloud. An eye-tracker registered their eye-movements. The test ended with an interview to measure the participant's satisfaction and to gather other comments.

The answers of the participants dealing with the space-time cube differed little from those dealing with the line cartograms. However, with the space-time cube, participants took on average more than twice as long to answer. This can be explained if one realizes that the space-time cube only shows the "raw" tracks while the line cartograms show interpreted data.

The objective of using the eye-tracker was only to get an impression of which views would attract attention depending on the type of questions asked. Because of this, the gaze data have not been analyzed further, as suggested by Coltekin et al. (2013). The questions were map, distance, or time oriented. If a question was time-oriented such as Question 8 in Table 1, one would expect many fixations on timelines. In Figure 7, three sample gaze plots, one for each question type, have been selected. Each displays the order and length of the participant's eye fixations.

Figure 7a shows a typical gaze plot that belongs to Question 2, a distance-oriented question. While thinking aloud, several participants remarked that they would only require the geography-to-time view to answer the question. In Figure 7b, a gaze plot from the map-oriented Question 9 is shown. The question could be answered by all views, but the strategy of most participants indeed was to look at the map and check all the control points. This particular participant found that one of the runners missed control point 6, which is revealed by the high concentration of long fixations in the south west of the map and the

Questions to be answered during evaluation
1. Did the two competitors follow the same path from target 1 to target 2? **[M]**
2. Which competitor ran the longest distance during the event? **[D]**
3. Which competitor took most time for the event? **[T]**
4. Who was the first to reach target 2? When did he arrive and depart again? **[T]**
5. Who ran a longer distance between target 3 to target 4? [D]
6. Who spent more time between target 2 to target 3? **[T]**
7. Who was faster when running from the start to target 1? **[T]**
8. Who spent more time while staying at target 3? **[T]**
9. Did the two competitors visit all the targets? **[M]**
[M] map oriented; **[D]** distance oriented; **[T]** time oriented

Table 1: User tasks.

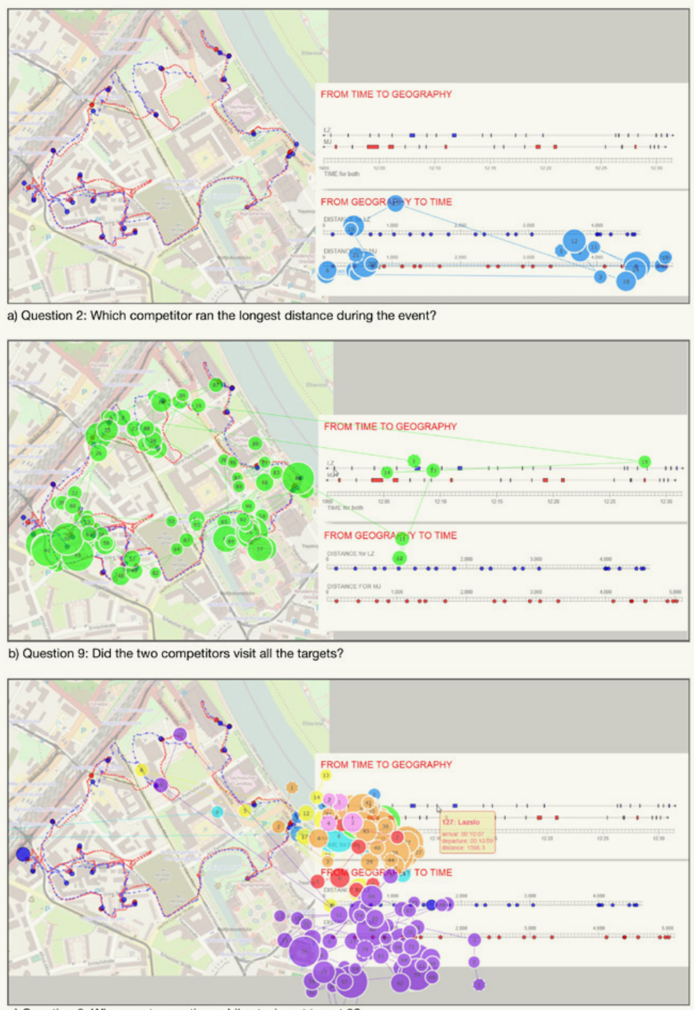

Figure 7: Gaze plots of a) Question 2 related to distances, b) Question 9 related to location, and c) Question 8 related to time.

fixations on both distance and timelines near control point 6 as well. The participant probably used these to confirm his findings in the map. In Figure 7c, the gaze plots of all eight participants for the time-oriented Question 8 are shown. All but one participant used the time-to-geography view to answer the question. This participant mentioned in the think-aloud session that he did not understand the line diagram very well. In all gaze plots of this participant, the gaze paths are extensive and mostly not in the relevant view. Of all participants, this one spent the most time looking at the screen before answering all of the questions.

CONCLUSION

This paper introduced an alternative for looking at movement data from different perspectives. The movements are schematized into lines and distorted based on time or distance in order to answer specific location- or time-based questions. We implemented our alternative in a web environment using D3, with different linked views that allow a user to explore the nature of the movements. Its strength is the ability to compare multiple movements. A simple preliminary evaluation of the product showed it does perform as expected, and that it is able to answer time and space related questions.

The method is expected to lose its advantage with high visual complexity. This is not necessarily due to the fact that there are many movement trajectories to represent and/or many stops involved. Rather, the spatial and temporal distribution of both the trajectories and/or stops will ultimately decide on the complexity. However, some interaction technique to visually unclutter the trajectories while exploring the data, as used in the online bus example, can be helpful.

Dealing with both qualitative and quantitative attribute data on the time and distance lines (the integration of the flow map) will be one of the first follow-up steps in this project, as well as experimenting with many more tracks, which will require specific "comparison" functionality.

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PEER-REVIEWED ARTICLE

Sea Level Rise Maps: How Individual Differences Complicate the Cartographic Communication of an Uncertain Climate Change Hazard

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Interactive, online maps of sea level rise have great potential for communicating climate change, as evidenced by both their popularity and likely ability to combat discounting of climate change hazards. However, little is known about how different audiences will interpret the significant uncertainties—including those related to the amount, timing, and spatial coverage of sea level rise flooding—communicated on many of these maps. A review of the risk perception literature presents three situations where different aspects of uncertainty have been suggested to dictate (or at least strongly encourage) adaptive or mitigative action in the context of sea level rise or similarly uncertain hazards, then problematizes these accounts by showing how context and personal differences mediate (and in some cases reverse) these expected relationships. A final section offers preliminary reflections on the implications for the cartographic communication of climate change and sea level rise uncertainty.

KEYWORDS: sea level rise; uncertainty; individual differences; climate change; interactive online map

INTRODUCTION

Maps have great potential for communicating climate change (Deitrick and Edsall 2009), and of the many ways of mapping climate change, maps of sea level rise may be one of the most popular (Preston et al. 2011) and powerful (Monmonier 2008) for reaching a general audience. Maps may be more familiar and comprehensible to novice users than graphs and other ways of visualizing climate change (Schnotz 2002), and have been shown to be more engaging than text alone for communicating climate change information (Retchless 2014). Sea level rise is a popular topic on climate change maps. Preston et al. (2011) found that sea level rise was one of the more popular topics on academic maps of climate change vulnerability, and of the 25 online, interactive water level visualization tools studied by Roth et al. (in press), 21 include depictions of sea level rise. Evidence suggests that these maps are not only widely available, but may also be one of the more frequently sought after types of climate change map. According to a Google Trends analysis for 2007 to 2014, searches for "sea level rise map" have been almost as frequent as searches for the more general "climate change map," and are becoming more popular (see Lang [2014] for a discussion of how Google Trends can be used to assess Internet users' information seeking behavior). During May 2014, the Trends analysis shows that searches for "sea level rise map" spiked to more than twice the highest previously recorded level for either search term (Figure 1).

With their increasing popularity, sea level rise maps have gathered a diverse set of producers and users, potentially complicating the communication of this already complex and uncertain hazard. As described in Roth et al. (in press), government agencies, non-profits, universities, private-industries, and news organizations have all produced interactive, online sea level rise maps in recent years. Academics have also been active in the production of non-interactive maps of sea level rise vulnerability for at least 15 years (see review in Preston et al. 2011). Audiences for sea level rise maps are similarly diverse, including scientists, policymakers, bureaucrats, educators, and,

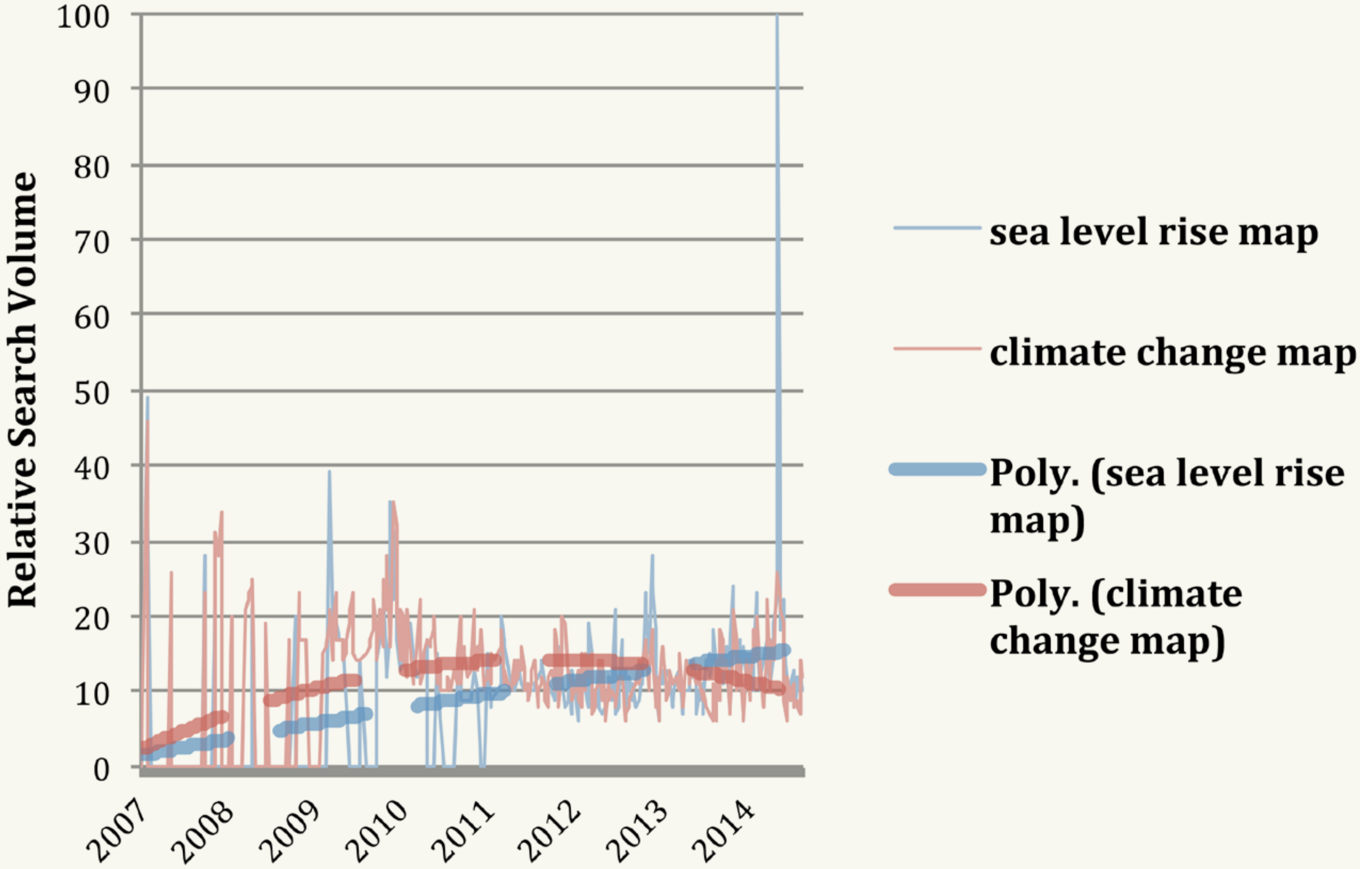

Figure 1: Weekly Google Trends comparison of the relative search volumes for the terms "sea level rise map" and "climate change map," including second degree polynomial trend lines. A score of 100 indicate the highest search volume in the dataset. Search volumes for sea level rise maps have been increasing, and recently spiked to more than twice their previous highest value. This spike may have been driven by increased interest in sea level rise following widespread media coverage of a study predicting the collapse of part of the West Antarctic Ice Sheet (Joughin et al. 2014).

increasingly, members of the general public (Monmonier 2008; Kostelnick et al. 2013). Designing maps that clearly communicate both the sea level rise hazard and its uncertainty to users with multiple levels of domain and map-user expertise is a significant and important challenge (Kostelnick et al. 2013).

This article explores the advantages and challenges associated with using the increasingly popular medium of sea level rise maps for communicating climate change. It first discusses how, by displaying impacts that are local and tangible, sea level rise maps may be less likely than other depictions of climate change to promote discounting, and therefore more engaging. Next, it identifies the significant uncertainties associated with sea level rise mapping and describes how they can pose challenges to climate change communicators—particularly given the complex ways in which these uncertainties may interact with individual differences to affect how audiences understand and evaluate the sea level rise hazard. A final section offers general considerations for the design of sea level rise maps in light of these advantages and challenges.

ADVANTAGES OF SEA LEVEL RISE MAPS: COMBATING DISCOUNTING

The popularity of sea level rise maps may be related to their ability to make the global, complex, and chronic hazards of climate change local, tangible, and personally meaningful. The climate change communication literature suggests that such a transformation can be challenging. Surveys of US residents have found that while most are interested in learning more about climate change, they also believe it will affect others more than themselves, and therefore may not be inclined to take action to address the issue (Maibach et al. 2009). Such discounting leads many to downplay the personal importance of climate change hazards, believing that any negative impacts will primarily be felt in the distant future, by people who live far away, or by the non-human natural world (Nicholson-Cole 2005; Leiserowitz 2007; Lorenzoni et al. 2007; Swim et al. 2009). Given the culturally and politically charged state of discussions about climate change, discounting may also be used (as part of motivated reasoning) to dismiss beliefs about climate change hazards that are inconsistent with one's worldviews or political brand (Kahan et al. 2011).

Several features of online sea level rise maps may diminish this discounting. To illustrate these features, this paper uses two of the more popular examples of online sea level rise maps: NOAA's *Sea Level Rise and Coastal Flooding Impacts Viewer* (**coast.noaa.gov/digitalcoast/tools/slr**, Figure 2) and Climate Central's *Surging Seas* (**sealevel.climatecentral.org**, Figure 3). First, these maps make sea level rise local, displaying it at the level of neighborhoods and city blocks, and making clear that—at least for residents of coastal areas—the sea level rise hazard is one that will likely strike close to home. This perspective casts sea level rise as a potential threat to one's identity as a member of the local community, potentially discouraging discounting and weakening the role of broader political and cultural commitments in shaping beliefs about climate change (Kahan et al. 2013). Monmonier (2008, 67) predicted the power of such a local perspective, claiming that large-scale maps that show sea level rise on top of local road networks "could be a powerful message for coastal residents," particularly if published in an interactive, online format. Second, the maps make sea level rise tangible. For example, the NOAA map displays not only the extent of inundated land, but also provides clickable placemarks that use pictures to simulate what sea level rise flooding might look like at several local landmarks. Similarly, the Climate Central map shows the locations of local schools, police stations, and other critical infrastructure that may be threatened by sea level rise. These depictions of flooding of well-known places make clearly visible the effects of climate change, which are often diffuse, difficult to observe directly, and emerge only through analysis of trends and averages over large temporal and spatial scales

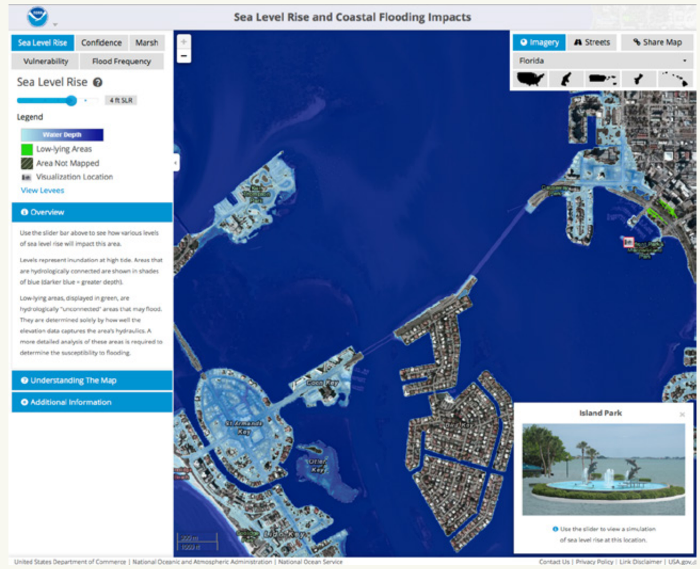

Figure 2: NOAA's Sea Level Rise and Coastal Flooding Impacts Viewer.

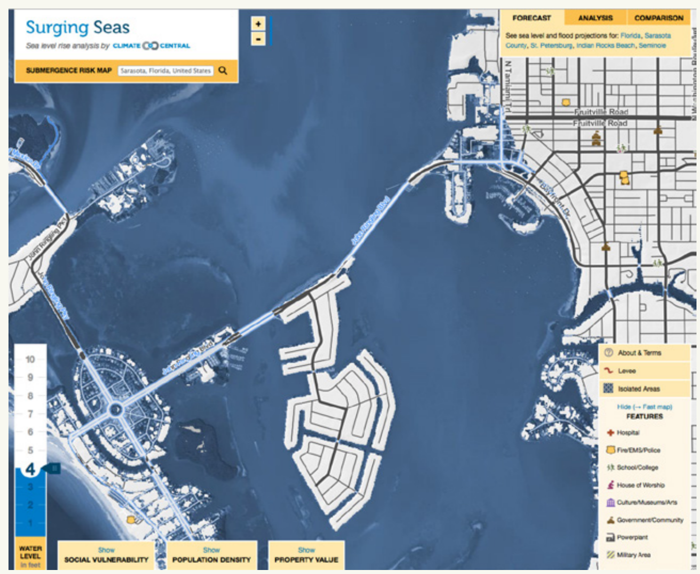

Figure 3: Climate Central's Surging Seas.

(Hawkins and Sutton 2009; Moser 2010). Third, these online maps make sea level rise personally relevant. The pan-and-zoom interfaces encourage map users to explore and zoom in on locations that are personally meaningful, whether in their own hometowns, favorite vacation destinations, or places of symbolic importance. As argued by Bostrom et al. (2008), such interactive features can allow users to customize hazard maps to suit their needs and interests, facilitating personal engagement with the sea level rise information.

Although online interactive sea level rise maps may hold great potential for communicating climate change, at least one feature of these maps may prove challenging for some audiences: their depiction of the multiple, interacting uncertainties that are inherent to the sea level rise hazard. This section reviews three perspectives on sea level rise uncertainty—two from cartography and one from economics and decision sciences—and applies them to NOAA's *Sea Level Rise and Coastal Flooding Impacts Viewer*. It then considers cartographic depictions of sea level rise uncertainty from the user perspective, concluding with examples of three ways in which individual differences may affect map users' understanding of and responses to uncertain sea level rise information.

THREE PERSPECTIVES ON SEA LEVEL RISE UNCERTAINTY

While authors from many different academic disciplines have considered sea level rise uncertainty, perspectives from two disciplines—cartography and GIScience, and the economic and decision sciences—are particularly relevant to this discussion of how maps can promote sea level rise awareness, engagement, and action. Perspectives from the cartographic and GIScience literature emphasize the components of sea level rise information that may be uncertain (Kostelnick et al. 2013) and the types of uncertainty that may be associated with these information components (Roth et al. in press), while perspectives from the economic and decision sciences tend to emphasize the level of precision in the measurement or expression of these types of uncertainty (Willows et al. 2003). This list is not exhaustive. For example, from a modeling and prediction perspective, sources of uncertainty—such as unknowns concerning future economic development pathways and associated greenhouse gas emissions—are often an important consideration (Dessai and Hulme 2004; Hawkins and Sutton 2009). Although the discussion below occasionally mentions sources of uncertainty, it focuses on how the three perspectives from cartography/GIScience and the economic and decision sciences have been used to study sea level rise communication.

UNCERTAINTY IN THE COMPONENTS OF SEA LEVEL RISE INFORMATION

In the sea level rise context, the two cartographic/GIScience perspectives have generally been used to explore how elements of map design such as visual variables and map interaction can be used to communicate uncertainty. Kostelnick et al. (2013) consider how visual variables and map interaction are used on sea level rise maps to communicate uncertainty related to the spatial, temporal, and attribute (framed as "natural process") components of geographic information, noting that MacEachren (1992) identified these three components as essential to uncertainty representation. These components of sea level rise information accrue uncertainty from several sources. Uncertainties about future emission pathways and oceanic/atmospheric response introduce significant attribute and temporal uncertainty: how much will sea levels rise, and when (IPCC 2013)? Moreover, digital elevation models and tidal transformations introduce spatial uncertainty into any mapping of a specific amount of sea level rise (NOAA 2010). Kostelnick et al. (2013) describe how maps can communicate attribute and temporal uncertainty by presenting multiple scenarios for the amount of sea level rise at a specific time period (e.g., small multiples depicting low, medium, and high sea level projections for 2100). For communicating spatial uncertainty, Kostelnick et al. suggest either implying uncertainty in future shoreline position using techniques such as vignettes (an example of the visual variable focus); or limits on the ability to zoom-in on interactive maps; or explicitly representing this uncertainty by using different raster fills to show areas that are slightly above or below the projected inundation level.

Additional research may be needed to explore which types of cartographic interaction are best suited to representing uncertainties in the spatial, temporal, and attribute components of sea level rise information. As noted by MacEachren et al. (2005) and detailed by Roth (2013), the effectiveness of visual variables for representing uncertainty has been widely explored, but comparable work matching interaction techniques to the communication of these uncertainties has been lacking.

UNCERTAINTY TYPES ASSOCIATED WITH COMPONENTS

Deploying the second cartographic/GIScience perspective on sea level rise uncertainty, Roth (2009b; in press) has considered how different *types* of uncertainty are used in inundation mapping. The uncertainty types considered in both studies are drawn from MacEachren et al. (2005), who present nine ways in which geospatial information may be uncertain: accuracy/error, precision, completeness, consistency, lineage, currency, credibility, subjectivity, and interrelatedness. MacEachren et al. (2012) simplify this list, retaining accuracy/error and precision as separate types but grouping the remaining seven, more "subjective" types of uncertainty into the collective type of "trustworthiness." Roth (2009b) performed a qualitative assessment of the appropriateness and influence of all nine uncertainty types for floodplain mapping, which is similar to sea level rise mapping in its concern with delineating "hypothetical supplementary shorelines," but differs in its authoritativeness, audience, uses, and scale (Monmonier 2008, 49). He found that experts in floodplain mapping considered all nine types appropriate, with accuracy/error, precision, and currency considered particularly influential for decision making. Meanwhile, Roth et al. (in press) considers how the nine different types of uncertainty are communicated using visual variables in a collection of 25 interactive, online sea level rise maps. He finds that only seven of the maps use the visual variables to represent one of the uncertainty types, that the only uncertainty types represented are completeness and "confidence" (which he considers similar to trustworthiness), and that only one map (the NOAA *Viewer*) represents both types. When these uncertainty types are represented, some combination of grain and color value are used to represent completeness, while the dimensions of color (hue, value, and saturation) are used for representing confidence.

While not dealing specifically with sea level rise, MacEachren et al. (2012) suggest that combining these two cartographic perspectives could inform the selection of visual variables for representing uncertainty. When combined, these two perspectives describe both *what* is uncertain (location, time, or attribute) and *how* or in what manner it is uncertain (in terms of accuracy, precision, or trustworthiness). MacEachren et al. (2012) show that visual metaphors for each combination of the "what" and the "how" of uncertainty can inform the design of iconic symbols for these combinations, and test the intuitiveness of these symbols in a user study. A similar study could extend this research by considering what symbols map users find most intuitive for the nine possible combinations of "what" and "how" of uncertainty on sea level rise maps.

LEVEL OF PRECISION IN THE MEASUREMENT OR EXPRESSION OF UNCERTAINTY TYPES

From the perspective of the economic and decision sciences, uncertainty in sea level rise and climate change is often considered in terms of its level of precision in measurement or expression, which is seen as a key factor in decision making. In their exploration of climate adaptation under uncertainty, Willows et al. (2003) contrast the process of decision making under precise uncertainty—as in games of chance and other situations where outcomes and consequences can be assigned probabilities and considered quantitatively—with decision making under imprecise uncertainty, where these probabilities are unknown or unknowable and therefore more amenable to qualitative analysis. Following a distinction first made in the economics literature by Knight (1921), these two conditions are commonly referred to as decision making under risk and decision making under uncertainty, respectively. In the climate change context, such conditions where uncertainty is not quantified, bounded, or defined have also been referred to as "deep uncertainty" (Kandlikar et al. 2005; Moser 2005). Bankes (2002) claims that this, too, has roots in economics, with the term "deep uncertainty" first used in this context by economist Kenneth Arrow in a talk on the Economics and Integrated Assessment of Climate Change offered at the Pew Center Workshop in 1999. Willows et al. (2003) argue that when precise probabilities cannot be assigned to decision outcomes for climate adaptation, decision makers' choice of adaptation strategy will be highly dependent on subjective factors such as the heuristics they deploy and their attitude towards the risk. Kandlikar et al. (2005) identify several such factors that may bias risk perception when probabilities are imprecise, including ambiguity aversion, conflict aversion, and ignorance aversion. Similarly, Moser (2005, 364) suggests that sea level rise policymaking and management under deep uncertainty are sensitive to "values, cognitive processes, and attitudes."

Much of this work has focused on how to describe and communicate these deep uncertainties to the public and decision makers. In an approach subsequently adopted by the Intergovernmental Panel on Climate Change (IPCC) for its Fifth Assessment Report (Mastrandrea et al. 2010), Kandlikar et al. (2005) suggest communicating uncertainties based on the precision with which they are known. They identify six levels of precision, with each matched to a different communication strategy. These levels range from situations where probabilities are well known and depiction using a full probability density function is appropriate; to less precisely known probabilities that are best described in terms of bounds, orders of magnitude, or the expected sign or trend direction; to states of effective ignorance, where quantitative descriptions are inappropriate and should be replaced with qualitative discussion of the available evidence and level of agreement (Kandlikar et al. 2005; Mastrandrea et al. 2010).

Researchers have yet to consider how these levels of precision might apply to the types of uncertainty identified by MacEachren et al. (2005). Of the nine types, accuracy/error and precision seem well suited to more precise levels of numeric expression, while the seven other types (grouped together as trustworthiness) seem likely to be more subjective, less precisely understood, and therefore communicated more qualitatively. Roth (2009a, 36) hints at this, noting that the level of precision for the map legends used in his study had to be adjusted so that "categories commonly reported at the ratio level (e.g., precision/resolution)…match[ed] uncertainty categories commonly reported at the ordinal level (e.g., credibility)." This suggests that each of the uncertainty types may commonly be associated with a specific level of measurement or precision; however, less common combinations of type and precision level (such as highly precise reports of consistency based on a survey describing expert agreement and its margin of error, or low-precision reports of accuracy as within or beyond tolerance) are certainly possible. Interestingly, Roth (2009a, 36) grounds his discussion of precision levels not in literature describing a hierarchy of precision in uncertainty representation (e.g., Kandlikar et al. 2005), but in work by Beard and Mackaness (1993) describing a three-level hierarchy of precision (and difficulty) in geographic uncertainty assessment tasks: 1) notification that the geographic data are uncertain; 2) identification of the type and relative amount of uncertainty; and 3) quantification of the exact amount of uncertainty. This task hierarchy calls attention to the importance of the map user in determining the precision with which cartographic features communicate uncertainty. Uncertainty may be presented with great precision, but if map users lack expertise for reading probability density functions or other similarly precise uncertainty presentations, then they will probably understand such presentations only at the notification or identification level—if they recognize them as indicators of uncertainty at all. More studies are needed to consider this relationship between user expertise and levels of precision in uncertainty, both as expressed in representations and as understood through tasks.

APPLICATION OF THREE PERSPECTIVES TO NOAA VIEWER

An examination of the NOAA *Viewer*'s communication of uncertainty from all three perspectives suggests that they are compatible, and may be applied simultaneously to better understand how sea level rise maps communicate uncertainty. For the three components of sea level rise information, the NOAA *Viewer* explicitly communicates the uncertainty about the attribute and spatial components cartographically: for uncertainty about how much sea levels will rise, an interactive slider allows the user to select different amounts of sea level rise and explore the extent of flooding they may cause using the dynamically updated inundation overlay; for uncertainty about the extent of inundation for a given scenario, a "confidence" overlay shows which areas have a high probability of flooding under the scenario, and which areas have a lower (but still significant) probability. Although temporal uncertainty is not explicitly represented on the NOAA map, its interactive slider for selecting sea level rise amounts may imply temporal uncertainty by presenting an ordered sequence of sea level rise scenarios that "suggests the passage of time" but does not assign specific dates (Kostelnick et al. 2013, 213).

The *Viewer* also communicates at least two different types of uncertainty information. As described in Roth et al. (in press), the *Viewer* shows completeness by applying a hatching texture to areas for which sea level rise was not mapped due to limitations in the NOAA model and data. Additionally, the confidence overlay may communicate trustworthiness, accuracy/error, or perhaps both. Roth et al. (in press) contends that this overlay uses different hues to identify areas where its depiction of sea level rise inundation is more or less trustworthy; however, supplementary documentation (NOAA 2010) states that this overlay is generated via a statistical calculation of the accuracy with which an area can be considered inundated, given the selected amount of sea level rise and the cumulative error from the DEM and tidal model.

The precision with which the *Viewer* represents these uncertainty types is generally low. Completeness of the sea level rise overlay is shown at the nominal level, with the hatching showing areas not mapped. Despite being generated via a precise statistical calculation, confidence is shown at the ordinal level, using "high" and "low" categories. Since this tool is available to the public and does not require any training, these design decisions may reflect a desire on the part of NOAA to notify users of uncertainty without overwhelming them with highly precise information that would support more advanced uncertainty quantification tasks (Beard and Mackaness 1993). As discussed in the next section, user expertise is one of many individual differences that mapmakers may want to consider when deciding how to depict sea level rise and its uncertainty.

EFFECTS OF UNCERTAINTY AND INDIVIDUAL DIFFERENCES ON RISK PERCEPTION AND RESPONSE FOR SEA LEVEL RISE

Because spatial reasoning about the sea level rise hazard—including decisions about the risks to one's community, and whether landmarks within that community are worth protecting—often requires considering these uncertainties, it is important to understand how users of popular depictions of sea level rise (e.g., the NOAA *Viewer*) understand and act on them.

The available evidence suggests that including uncertainty information on sea level rise maps can be helpful to users. Several studies have suggested that including uncertainty on maps can improve decision outcomes (Deitrick and Edsall 2006; Brickner et al. 2007; review from Harrower 2003). In the climate change context, some authors have argued that including uncertainty in public communications may cut both ways, particularly when attempting to reach those who are doubtful or disengaged about climate change: while some map users may appreciate an honest depiction of uncertainty, this uncertainty may also lead others to underestimate risk or justify delaying adaptive action (Swim et al. 2009; Moser 2010). However, governments and public officials often need this uncertainty information to successfully assess climate change risks and prioritize the implementation of mitigation and adaptation to high-risk areas. Model means and consensus estimates may fail to capture outliers with important policy implications (Oppenheimer et al. 2007; Brown and Wilby 2012); for this reason, models that do not account for uncertainty have been found to significantly underestimate the protective response needed to cope with sea level rise (Lewandowsky et al. 2014). For a more general audience, including uncertainty information in climate change materials may promote public trust in climate science, since a range of possible futures may be seen as more credible than a single, worst case scenario (Sheppard 2005).

Authors have also considered both whether and how individual differences can affect map users' understanding of uncertainty information, and ultimately their decision making process. From the limited literature addressing the mapping of uncertain hazards, authors have stressed the importance of designing for different user groups (Hagemeier-Klose and Wagner 2009), including those with different "culture or knowledge" (Fuchs et al. 2009) and those who perform different types of tasks, with varying levels of data complexity (Pang 2008). These considerations may be even more important when the map is interactive, since "interactive visualization has the potential to allow users to tailor displays to reflect their individual differences" (Bostrom et al. 2008, 34).

Beyond these general insights, several authors have also considered specific ways in which one particularly important type of individual difference—map users' expertise—may affect their interpretation of uncertainty information about flood hazards. Roth (2009a) found that when shown a map with uncertain floodplain boundaries, map users with expertise—both in map use and especially in floodplain mapping—had higher risk assessments and assessment confidence than novices. He also noted a potentially dangerous combination of expertise: users who were map-use experts but flood-mapping novices had high confidence in their assessments, but significantly underestimated the risk relative to the domain experts, suggesting that they did not fully appreciate the potential for unfortunate surprises that the domain experts recognized in the uncertain data. In the sea level rise context, Kostelnick et al. (2013) describes a similar fear that novice users of sea level rise maps will not appreciate their significant spatial uncertainty, and will zoom in to levels not appropriate given the resolution of the data. Monmonier (2008) relates that, when faced with a similar concern regarding novice users' ability to interpret sea level rise maps, the US Environmental Protection Agency opted to produce versions with different descriptions of uncertainty for research papers, the popular press, and the general public. Roth (2009a) suggests that while such user-aware design approaches are desirable, uncertainty should not be relegated to marginalia, but should be represented explicitly on the map, where it will be difficult for novices to ignore. Deitrick and Edsall (2009) argue that such an approach is particularly important in the context of climate change media, where seemingly authoritative graphics in news reports communicate possible futures but generally not their own uncertainty.

This literature suggests two lessons: 1) including uncertainty information on sea level rise maps may promote more informed risk assessment and decision making; and 2) individual differences (particularly user expertise) will likely affect both how map users interpret these sea level rise uncertainties and how they act on them. However, mapmakers who heed these lessons will likely face additional, largely unanswered questions: which other individual differences are likely to have significant effects on the interpretation of uncertainties, and what will these effects be? The next three sections explore these questions, examining three examples of cases where individual differences may shape how map users understand and act on uncertainty in general, and sea level rise uncertainty in particular. These sections consider situations where aspects of each of the three perspectives on uncertainty described above have been suggested to dictate (or at least strongly influence) adaptive or mitigative action in the context of sea level rise or similarly uncertain hazards. They sketch out the reasons why these expected relationships are at least somewhat justified, and then problematize these accounts by showing how context and individual differences mediate (and in some cases reverse) these expected relationships. A concluding section discusses how these effects of individual differences on the interpretation of uncertainty may inform the design of sea level rise maps.

CERTAINTY IN THE SPATIAL, TEMPORAL, AND ATTRIBUTE COMPONENTS OF DAMAGING SEA LEVEL RISE ENCOURAGES MORE ADAPTIVE AND MITIGATIVE ACTION

Several authors have suggested that when people perceive a threat as more likely—e.g., when spatial and temporal certainty of a damaging amount of sea level rise is seen as high—they are more likely to take action to respond to the threat. Thus, in the model of climate change adaptation proposed by Grothmann and Patt (2005), risk appraisal (a combination of perceived probability and severity) is an important driver of adaptation intentions. Working with a similar model, Grothmann and Reusswig (2006) confirmed that risk appraisal was a significant predictor of protective responses for flooding. Moreover, while not studying the effect on protective responses, Severtson and Myers (2012) found that study participants assigned to higher risk zones on a map of cancer risk generally had stronger risk beliefs.

For sea level rise, this suggests that people in areas where inundation is more likely should also be more likely to take adaptive or mitigative action. But this willingness to take action will likely also depend on the characteristics of the hazard and individual differences. If the sea level rise threat is seen as so great that it overwhelms an individual's perceived adaptive capacity, then being located in a high-risk zone might lead to a fatalistic response. For example, Howe (2011) proposes that fatalism may explain why businesses at the highest risk of storm surge flooding took the fewest adaptive actions. Grothmann and Patt's (2005) model acknowledges that such maladaptive responses (also including denial and wishful thinking) will often dampen the response to climate threats.

Beyond such "maladaptive" responses, people may also differ on what they feel is an acceptable risk (Nicholson et al. 2005). Thus, there is unlikely to be an objective way to determine a single probability value for sea level rise above which it would be logical to take personal action (such as moving away from the risky location). Some people may value the immediate amenities of living near the ocean highly enough to bear an almost certain risk of inundation in 2050 or 2100, especially since they are likely to significantly discount the inundation risk at these times several decades in the future. This is supported by a series of studies of home values and risk perception in the Houston area, which found that proximity to the ocean was seen as both an amenity and a hazard, with conflicting effects on home value (Zhang et al. 2010; Lindell and Hwang 2008).

SOME TYPES OF UNCERTAINTY ARE GIVEN GREATER WEIGHT THAN OTHERS IN DECISION MAKING

The type of uncertainty presented to map users may also affect their decision making. For example, uncertainty may be used quite differently in decision making when it is communicated as consistency in opinion among a panel of experts rather than as a model-based expression of accuracy or precision. For example, Patt (2007) found that students' subjective estimates for the likelihood of a certain amount of sea level rise were closer to 50/50 if the probability of the sea level rise was presented as a level of agreement among experts, rather than as a model-based probability estimate. This suggests a significant effect of the type of uncertainty (and possibly the message source) on how uncertainty information is weighted in the decision process.

However, it cannot be assumed that everyone will ascribe the same uncertainty types to information about sea level rise. In an example from Patt (2007), a person who does not trust climate modelers may believe that a modeled probability of sea level rise is also highly subjective and discount it accordingly. This is in line with Wachinger et al.'s (2010) finding that trust in experts and authorities was one of the most frequently cited factors associated with higher risk perceptions and more protective actions for natural hazards. While there is probably no objectively correct way to weight disagreement among expert predictions, engaging with residents and stakeholders through participatory exercises may build trust (Wachinger et al. 2010). This could help to fight the perception among the disengaged and dismissive that scientists remain divided on whether climate change is happening and will have harmful effects.

Additional research is needed to explore the comparative weight given to uncertainty types other than consistency/subjectivity and accuracy/precision in the sea level risk assessment context. The results of such studies could help mapmakers' choose uncertainty types that users are less likely to interpret in ways that run counter to the accepted science.

WHEN UNCERTAINTIES ARE EXPRESSED IMPRECISELY, RISK PERCEPTIONS ARE HIGHER

Economists and decision theorists have found that, when people are presented with a low to moderate—but imprecise—probability of a hazardous event (such as sea level rise flooding), they are likely to skew their perception of the risk towards the worst possible outcome (e.g., the highest probability of flooding possible given the imprecise specification) (Einhorn and Hogarth 1985; Kuhn 2000; Rustichini 2005). This finding is based on researchers' observation that people generally prefer to bet on outcomes with known, precisely specified probabilities rather than outcomes with vague or imprecisely defined probabilities (Ellsberg 1961), and will pay a premium to avoid or remove such vagueness or imprecision (Becker and Brownson 1964). Although generally referred to as "ambiguity aversion" in the economic and decision science literature (Ellsberg 1961; Becker and Brownson 1964), this tendency may be more properly termed "vagueness aversion," since imprecisely specified probabilities suggest a range of possible values, rather than the small set of distinct possibilities implied by ambiguity (Kuhn 1997).

This finding of greater risk perception under vagueness would seem to be readily applicable to sea level rise and climate change, where epistemic (limited knowledge about climate processes), natural stochastic (irreducible complexity of the climate response), and human reflexive (unknowns in the future socioeconomic system) elements all limit our ability to provide well defined probability estimates for specific climate outcomes (Dessai and Hulme 2004). Given the large uncertainties and the potential for highly disruptive impacts, the application of the first element of the precautionary principle—"taking preventive action in the face of uncertainty" (Kriebel et al. 2001, 871)—to climate change would appear to be an example of a response to uncertainty that would be in line with the expected increase in risk perception under vagueness. In line with this expectation, several authors have suggested that more should be done to communicate high-impact sea level rise scenarios (Oppenheimer et al. 2007; Nicholls and Cazenave 2010; Brysse et al. 2013), the apparent expectation being that the possibility (with small but unknown probability) of such a highly disruptive future should lead to adaptive or mitigative action.

However, as argued in Kuhn (2000), vagueness may not always increase risk perception, particularly for environmental problems and related hazards, where motivated reasoning may interact with vagueness to increase or decrease perceived risk. Kuhn (2000) found that prior environmental attitudes determined whether risk perceptions skewed towards the top or bottom of a range of probabilities given for an environmental hazard; this effect increased when the high and low ends of the range were associated with sources with a known bias. In a cartographic context, Severtson and Myers (2012) similarly found that when assessing risk in a high risk zone on a map, participants in a study were more likely to have lower risk beliefs if the boundaries of this high-risk zone were blurred in a way suggesting vagueness. Thus, rather than an unambiguously positive relationship between vagueness and risk perception that might suggest a clear role for the precautionary principle in the response to climate change, uncertainties in climate change impacts may also lead some people to lower their risk perceptions.

Individual differences in comfort and perceived competence with climate data may also affect vagueness aversion. While early attempts to model vagueness aversion focused on the effect of imprecise probabilities on decision-making (e.g., Einhorn and Hogarth 1985), later work suggested that the preference for precisely defined probabilities in such situations may be an example of a broader inclination towards choices that are well known (and about which one has some level of expertise, or a general "feeling of competence") over choices which are poorly understood (Heath and Tversky 1991). As a product of both imprecision in the underlying data and individuals' recognition and interpretation of this imprecision, vagueness aversion will thus be felt most strongly when these two factors (data and expertise) combine in ways that lead to a perceived lack of competence. Hope and Hunter (2007) have explored this interaction between expertise and vagueness aversion in a cartographic context; future work could consider this interaction as it applies specifically to sea level rise mapping.

CONCLUSIONS: LESSONS FOR MAPPING SEA LEVEL RISE AND OTHER UNCERTAIN CLIMATE FUTURES

What lessons does this literature hold for the communication of uncertainty on online, interactive sea level rise maps like the NOAA *Viewer* and Climate Central's *Surging Seas*? Perhaps most importantly, sea level rise map design demands a user-centered perspective. As a popular and powerful medium for communicating one of the more dramatic impacts of climate change on coastal communities, these maps appeal to many audiences, ranging from scientists and policymakers to members of the general public (Monmonier 2008; Kostelnick et al. 2013). Because sea level rise is a highly uncertain hazard, communicating this uncertainty to all of these diverse map users is likely necessary and important: for scientists and policymakers, it may improve decision outcomes (Deitrick and Edsall 2006; Brickner et al. 2007; review from Harrower 2003), and for members of the public more interested in general exploration of the sea level rise hazard, it may dissuade anchoring on a single scenario (Deitrick and Edsall 2009) and establish credibility by clearly indicating limitations in the data and models (Sheppard 2005; Spiegelhalter et al. 2011). Despite these general benefits of showing uncertainty on sea level rise maps, each of the many audiences these maps serve is likely to interpret these uncertainties somewhat differently (as shown for other hazard maps in Roth [2009a] and Severtson and Myers [2012]), suggesting the need for designs that are customized (or interactive and customizable) to address these differences. This may be particularly true in cases where individual differences can lead users to interpret uncertainties in ways that significantly underestimate risks (relative to expert assessments) or encourage maladaptive responses (see, e.g., Roth 2009a).

The examples reviewed in this article suggest at least two types of individual differences that may contribute to such dangerous distortions in map users' risk perception and response: user expertise and trust. Compared to domain and map-use experts, novices have been shown to have lower risk perceptions after studying a map of an uncertain flood plain (Roth 2009a); novices may similarly discount the possibility of high-end impacts on maps of sea level rise uncertainty. This is supported by work in the vagueness aversion literature, which has found that expertise can shape interpretation of imprecisely defined probabilities for hazardous events (Heath and Tversky 1991). Roth (2009a) suggests that despite novices' underestimation of flood risk, they may still take appropriate precautions because they also have lower confidence in their risk assessments, and may therefore be more likely to consult an expert. However, if the novice map users do not trust the relevant experts, then they may not seek or value their opinion. This may be particularly true for politically charged climate hazards such as sea level rise, where considerations such as the message source and type of uncertainty (Patt 2007) and users' prior environmental beliefs (Kuhn 2000) may affect their trust in the uncertainty shown on hazard maps (and experts' assessments of it). Prior beliefs about the environment in general and climate change in particular are therefore another individual difference that may shape sea level rise risk perceptions; others introduced in this article include hazard proximity and perceived adaptive capacity. More studies are needed to explore these in the cartographic context, and to identify additional individual differences that may also affect map users' interpretation of uncertainties on hazard maps.

In addition to identifying which individual differences are most likely to affect the interpretation of uncertainty, mapmakers must also decide whether and how to design for these differences. At the most basic level, this may include decisions about which components of geographical uncertainty should be shown, using which types of uncertainty, and at what level of precision; it may also include considerations of which representational techniques (e.g., visual variables and map interaction) should be used to communicate these uncertainties. The following list presents some general guidance on how mapmakers might approach these decisions in light of the literature considered in this article.

- Brysse et al. (2013, 327) argue that the scientific commitment to restraint, objectivity, skepticism, rationality, dispassion, and moderation has actually led climate scientists to generally err "on the side of least drama." Map makers should not shy away from dramatic presentations: visualizations showing projected impacts of sea level rise on local landscapes can drive home the personal relevance of rising seas (Nicholson-Cole 2005; Sheppard 2005), and when made engaging and interactive they may also encourage deeper understanding of complex scientific information (Rapp 2005). However, because such visualizations can be so convincing, they must be used with great care, and employ what Sheppard (2005) calls "permissible drama"—the idea that the map or visualization should remain grounded in a scientifically plausible (e.g., not exaggerated) future, and that goals of the visualization should be made explicit (e.g., raising awareness about the possible future impacts of sea level rise).

- Multiple authors (Deitrick and Edsall 2009; Roth 2009a; Spiegelhalter et al. 2011) have stressed that maps and other depictions of uncertain hazards such as sea level rise should clearly and prominently communicate their limitations. For interactive, online sea level rise maps, this suggests that mapmakers should strongly consider explicitly communicating uncertainties associated with all three components of sea level rise information: space, time, and attribute. While spatial and attribute uncertainty are already represented on some of these maps (including the NOAA *Viewer* and Climate Central's *Surging Seas*), mapmakers should consider representing temporal uncertainty more explicitly (rather than implying it using sliders and animation).

- Following the lead of MacEachren et al. (2012), mapmakers and researchers could explore the use of visual metaphors to represent possible combinations of uncertainty components and types on sea level rise maps. To extend this work, researchers could consider how adjusting the visual variables used to construct these metaphors might communicate uncertainty with different levels of precision.

- As discussed in Kostelnick et al. (2013), mapmakers should consider communicating uncertainty using map interaction as well as visual variables. This is an active area of research. For example, recent work by Roth (2012; 2013) explores a possible typology for map interaction primitives, and speculates about the use of map interaction to communicate uncertainty.

- The potential parallel between levels of precision in the expression of uncertainty (as described in the IPCC uncertainty guidance, Mastrandrea et al. 2010) and the hierarchy of precision (and difficulty) for uncertainty assessment (Beard and Mackaness 1993) may warrant further exploration. If user expertise can be matched with an appropriate level of assessment task, then perhaps this task level can be further paired with a corresponding level of precision in the cartographic presentation of uncertainty. This could perhaps lead to a better fit between map design and user expertise. However, as discussed in the above section on vagueness aversion, other individual differences (such as prior environmental beliefs) can also affect users' interpretation of imprecisely defined uncertainties, potentially complicating mapmakers' decisions about which level of precision is most appropriate.

- Mapmakers may also consider adjusting the production and presentation of their maps to help earn the trust of their audiences. Seeking these audiences' active participation in the design of sea level rise maps may help build trust in their depictions of sea level rise and its uncertainty (Patt 2007). Mapmakers should also consider which types of uncertainty might be considered most or least trustworthy for the map's intended audience, perhaps based in part on its predominant political or environmental beliefs.

Much of this guidance is preliminary. In particular, additional studies are needed to assess: which visual variables and forms of map interaction most effectively communicate different combinations of uncertainty types and precision in the sea level rise context; which individual differences most strongly affect interpretation of these uncertainties; and how the types, precision, and presentation of uncertainty might be adjusted to limit the effect of any individual differences that may strongly bias its interpretation. Nonetheless, it is hoped that by raising these questions and beginning to explore possible answers, this article will prove valuable both to researchers in the field of cartographic uncertainty representation and to designers of maps of sea level rise and other similarly uncertain environmental hazards.

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The Relationship Between Scale and Strategy in Search-Based Wayfinding

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We present the results of a study that investigated the interaction of strategy and scale on search quality and efficiency for vista-scale spaces. The experiment was designed such that sighted participants were required to locate "invisible" objects whose locations were marked only with audio cues, thus enabling sight to be used for search coordination, but not for object detection. Participants were assigned to one of three conditions: a small indoor space (~20 m²), a medium-sized outdoor space (~250 m²), or a large outdoor space (~1000 m²), and the entire search for each participant was recorded either by a laser tracking system (indoor) or by GPS (outdoor). Results revealed a clear relationship between the size of space and search strategy. Individuals were likely to use ad-hoc methods in smaller spaces, but they were much more likely to search large spaces in a systematic fashion. In the smallest space, 21.5% of individuals used a systematic gridline search, but the rate increased to 56.2% for the medium-sized space, and 66.7% for the large-sized space. Similarly, individuals were much more likely to revisit previously found locations in small spaces, but avoided doing so in large spaces, instead devoting proportionally more time to search. Our results suggest that even within vista-scale spaces, perceived transport costs increase at a decreasing rate with distance, resulting in a distinct shift in exploration strategy type.

INTRODUCTION

Modern navigation systems have, to a large degree, solved many of the technical limitations associated with wayfinding. GPS-enabled smartphones are ubiquitous, and are responsive to many user preferences, including least-time, shortest-distance, and preference for certain kinds of paths, among many others. In addition to preferences, differences in strategy have been invoked to explain differences in wayfinding behavior. Common examples of these include heuristics such as least-angle estimation (Hochmair 2005), higher order strategy sets (Lawton 1994), and personality influences (Pingel 2012).

Here, we investigate the role of scale and strategy in search-based wayfinding. Search-based wayfinding involves goal directed movement to a target with an unknown location and is distinct from access-based wayfinding in which the location of the target is known (Passini 1992). Although the conceptual difference between these two is clear, in practice the differences may be somewhat less distinct. Spatial knowledge is often imprecise, and many destinations are entirely new to the traveler (Montello 2005). The grey area between search and access-based wayfinding is perhaps best glimpsed when one considers the phenomenon of being "unknown lost," in which an individual has a belief about their position in the environment that is, in fact, mistaken (Crampton 1988).

Search is an integral part of navigation. This is particularly true during wayfinding, given that it often occurs on a continuum between unknown and known target locations in the environment, and with varying degrees of familiarity with the environment itself (Allen 1999). Wiener, Büchner, and Hölscher (2009) describe a complete taxonomy of wayfinding in which search is described as a type of wayfinding directed at a specific target where destination knowledge is unavailable. Just as the degree of knowledge of the environment or of target location will result in observable differences in wayfinding behavior, the extent or scale of the space permeates the problem, as individuals are likely to strategize differently at a local scale of travel than they will at a larger scale. Previous work (Tellevik 1992; Hill et al. 1993; Gaunet and Thinus-Blanc 1996) has identified how strategy impacts spatial layout learning and wayfinding at room-sized spaces. We extend this work by examining how larger spaces impact strategic behavior and how strategic reasoning changes as the size of the problem space increases.

BACKGROUND

Much of the early work on spatial search and evasion strategy originated in response to World War II, and the problem of locating the machines of war. Koopman (1956a; 1956b; 1957) and Gould (1966) provided the mathematical basis for search in both real world contexts and in information theory. Within real-world contexts, Koopman found that the inverse of the cube of the distance between the searcher and the target was proportional to the probability of detection for many types of distance-detection schemes, including visual, sonar, and radar searches. This inverse cube law still serves as the basis for modern search and rescue operations (National Search and Rescue Committee 2000; Hill, Carl, and Champagne 2006). Much of Koopman's work was adapted by Isaacs (1965) and Gal (1979; 1980) to create spatially explicit game theoretic models.

An important element in search for stationary targets is the avoidance of searching the same space more than necessary. Truly random searches disobey this central tenant, and as such are relatively inefficient. Given the relatively high costs of conducting large-scale searches (of opposing military hardware, persons lost in the wilderness, drug interdiction, or any other well-hidden object), many systematic strategies of searching exist. Perhaps the most common of these is the parallel or gridline search (Koopman 1956b; Hill et al. 1993), which is most useful when no information about the location of the target is known. This search pattern manifests as a series of parallel transects, and is common to nearly every search environment (National Search and Rescue Committee 2000). The distance between parallels, or track spacing, is determined by a detection function, which tends to be high near the searcher and drop to zero some distance away, and is influenced by the method of detection and other characteristics of the searcher, the target, and the environment. When more specific information about the location of the target is known, an improved strategy is to make an initial guess about the location of the target followed by outward-moving concentric squares or circles. This tends to concentrate the search in the most likely areas first, leaving less likely areas last. In conditions where detection is particularly difficult (i.e., where probability of detection is significantly less than one, even at the maximum), repeated searches of the same space are often justified.

In many cases, large areas are subdivided into smaller spaces, to which any of the above systematic searches may be applied. These segmented spatial search strategies may take a variety of forms, with sector searches and rectilinear subdivisions the most common. In addition, most of the above strategies assume adequate personal or map-based knowledge of the area in question. When this is not the case, perimeter searches are often quite valuable in learning the overall spatial layout (Hill et al. 1993), and can be combined with inward spiraling square or circular patterns to exhaustively search the space.

Heth and Cornell (1998) describe the ways in which an understanding of lost person behavior constrains search and rescue efforts to minimize search time and cost, and maximize the preservation of life. The use of a geographic information system as an aid to planning and conducting a search allows for a non-uniform treatment of a search area, so that simple spatial patterns, like the gridline search, can be targeted (Heth and Cornell 2007). Heth and Cornell additionally point out that most search and rescue operations are large enough to require complex sets of social and operational hierarchies, and they explicitly compare these hierarchies to the naval navigation teams described by Hutchins (1995). At the apex of the entire operation, search coordinators ultimately define the strategy for searching, often using non-spatial information about the target (e.g., a determination that the target was interested in photography, not fishing) to constrain the spatial search.

Thus far the consideration of search targets has been confined to targets whose quality (as targets) is binary—things that either are or are not what we are looking for. Early on, however, geographers also examined search as it relates to consumer behavior—searches for goods and services. In such cases, the quality of the target varies, and the termination of the search itself depends a great deal on issues of satisfaction (Golledge and Brown 1967). Searches of this kind also tend to be preferentially carried out in areas with which the searcher is already familiar (Cyert and March 1963). Hudson (1975) compared trade-offs between distance-of-travel and the reduction of uncertainty implicit in consumer types of searches involving recent migrants to an area, using shopping center size as a proxy variable that was inversely related to uncertainty. His results revealed that while distance overwhelmed uncertainty as a determinant in search behavior for individual shops, at the shopping center level the reverse was true. Apart from very interesting level-of-analysis concerns, these results suggest that the minimization of uncertainty partially explains search behavior, especially when paired with the observation of Cyert and March (1963) that searches tend to be preferentially concentrated in familiar areas.

Tellevik (1992) explored the hypothesis, based on the work of Fletcher (1980a; 1981b; 1981c), that systematic search strategies would improve learning of objects within a space. To this end, ten blindfolded sighted participants were asked to search a furnished room (6.2 × 5.2 m) for four objects. Participants completed the task twice, with the objects and furniture moved between trials. Tellevik recorded the frequency of gridline searches, perimeter searches, and reference-point usage, in which participants used an object or a wall to help fix the location of another object. At the end of the task, participants provided distance estimates via pairwise comparisons and built a model of the space. The results of his study revealed that strategy type changed markedly between trials. In the first trial, participants made extensive use of both perimeter and gridline searches, spending an average of 98% of their time using these kinds of searches, and only 2% of their time on reference-point use. This indicates that strong attention was given to the "find" portion of the task, and relatively less attention to the "remember" portion of the task. Overall search time in the second trial was nearly half that of the first trial but use of the reference-point strategy grew from about 2% in the first trial to 45.5% in the second trial. Interestingly, this dramatic shift did not result in any significant improvement of participants' knowledge about the locations of the objects in the room.

Hill et al. (1993) extended Tellevik's experiment to investigate strategies of visually impaired participants (rather than blindfolded sighted participants) who were asked to search a similarly sized space (4.6 × 4.6 meters) for four objects. The strategies were coded in the same manner as Tellevik, except that reference points were distinguished (object-to-object, object-to-wall, and object-to-start), and participants completed only one trial. Participants were evaluated on their learning of the spatial layout through several pointing tasks, for which an overall score of accuracy (mean absolute error) was recorded. These scores served as the basis to isolate the top (M = 17.3 degrees of absolute angular error) and bottom (M = 90.7 degrees) performing fifteen participants, out of an initial 65.

Good performers tended to report using and were observed using more strategies (both search and memorization-related) as a group than were poor performers, with the interesting exception that no one (good or poor) reported using a gridline search in post-task interviews, though such searches were actually conducted. Good performers tended to complete the task in less time, and also tended to use more reference point visits of every type. Gridline searches were relatively rare for both good (30%) and bad (10%) performers, but the latter used perimeter searches nearly twice as often as good performers, though they verbally reported using fewer. This result supports Pingel's (2012) claim that the ability to externalize one's strategy is an important element of a strategic disposition in that it demonstrates a more complete awareness of one's strategy.

A second extension of the Tellevik (1992) experiment focused on the differentiation of object-linking memorization strategies. Gaunet and Thinus-Blanc (1996) found that blindfolded sighted participants tended to use "back-and-forth" object-linking strategies (a series of sequential visits between the same pair of objects), while early blind participants were likely to use cycles of visits, where each of the four objects was visited sequentially. These cycles of visits led to poorer overall spatial layout learning when compared to participants that used back-and-forth object links. Importantly, Gaunet and Thinus-Blanc demonstrated that neither performance nor selection of strategy type was linked to a measurement of participant IQ.

Many types of wayfinding experiments in general, and search experiments in particular (e.g., Ruddle, Payne, and Jones 1999) have been conducted in virtual spaces. While many of these glimpses into spatial cognition generalize well to non-virtual contexts, scale is a particularly difficult concept to model in a virtual environment, since this conflates real world figural spaces—tabletop, manipulable spaces smaller than the body—with larger scale spaces. In addition to figural space, Montello (1993) distinguishes between three other scales of spaces: vista, environmental, and geographical, divided largely based on the degree to which locomotion is a factor in learning the space, and whether the space is larger or smaller than the body. Used in this way, scale acts as a function of *extent* or *size*. Vista scale spaces are those in which the space may be apprehended from a single location, without appreciable locomotion, and would include both room-sized spaces as well as larger spaces like campus greens or town squares. Interaction with virtual spaces, either through a desktop or via a fully immersive virtual environment, will nearly always blur the lines between the experienced and represented scales (Pingel and Clarke 2012; Waller, Hunt, and Knapp 1998). The construction of psychologically-based categories of scale rests on the notion that individuals' thinking and behavior in different kinds of spaces will be more alike within groups than between them, and Montello (1993) offers evidence to this effect. We offer evidence, via a controlled experiment, that shows that search behavior within vista sized spaces is highly variable, thereby suggesting a refinement of Montello's taxonomy may be necessary.

METHODS

The experimental setup was inspired by the work of Tellevik (1992), Hill et al. (1993), and Gaunet and Thinus-Blanc (1996) in which participants were asked to find and remember the locations of four objects in a vista-scale (Montello 1993) space. However, unlike these experiments, participants searched in one of three possible scale conditions: (1) an indoor (small) space, measuring 4.6 × 4.6 meters (area: 23.3 m^2); (2) an outdoor (medium) space, measuring 13.8 × 18.7 meters (area: 258.0 m^2); or (3) an outdoor (large) space, measuring 23.1 × 43.0 meters (area: 993.3 m^2). Here, scale refers to the extent or absolute size of the space.

In addition, rather than searching for physical objects, participants in our experiment searched for *invisible objects*: locations in the space marked with audio cues. That is, when a participant walked within range of four defined trigger areas, they would hear the sound marking that particular location. In this way, participants could use vision to coordinate locomotion and search, but not to locate objects. Details about the search spaces and the arrangement and sizes of trigger spaces are shown in Table 1 and Figure 1.

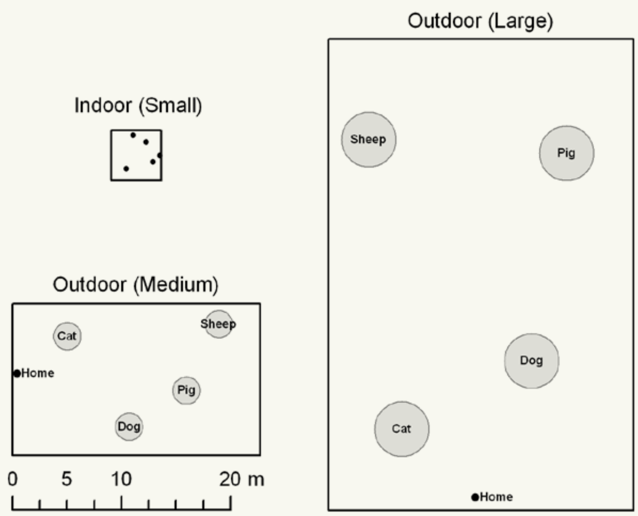

Figure 1: Comparison of sizes and trigger areas for search sites.

	small	medium	large
dimensions (m)	4.6 × 4.6	18.7 × 13.8	43 × 23.1
area (m2)	20.9	258.8	993.6
trigger diameter (m)	0.6 – 1.0 (est.)	2.5	5.0
trigger area (m2)	.46 (est.)	4.9	19.6
trigger ratio (A/TA)	45.8	52.7	50.6

Table 1: Comparison of sizes and trigger areas for search sites.

PARTICIPANTS

Forty-eight individuals participated in the experiment; all were drawn from introductory geography courses and participated in exchange for extra credit. Twenty-one of these were male, and the mean age was 20.8 (SD = 3.9). Fourteen participants searched the small space, 16 searched the medium space, and 18 searched the large space, and the ratio of males to females was approximately equal in all conditions. No participants reported any hearing impairment that would preclude participation in the study, and all were able to respond appropriately to speech and sample audio cues. Written informed consent was obtained according to the provisions set by the University of California, Santa Barbara (UCSB) local institutional boards.

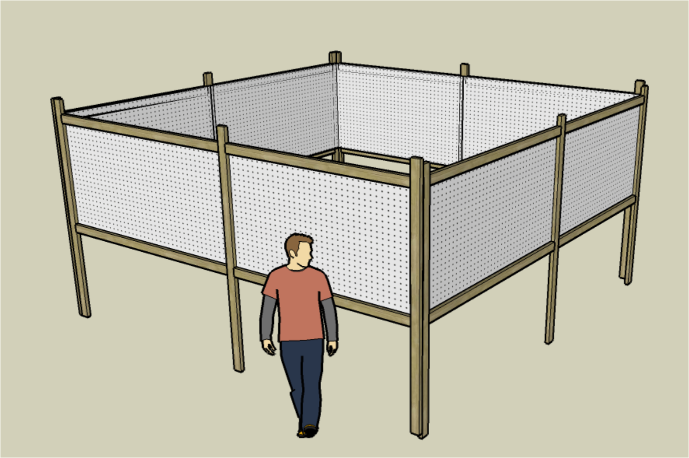

Figure 2: Diagram of the indoor search space.

MATERIALS

The small search space was constructed from a wooden frame and several pieces of thick pegboard (Figure 2). There were no obstacles in the room. The room was housed in a large human geography laboratory on the UCSB campus.

Audio cues alone marked the location of each of four "objects" that each participant attempted to find. The sound cues for each object location were transmitted to the participant via a pair of Bluetooth wireless headphones. The location of each participant was tracked through thirty, low-power (<1 milliwatt) red lasers and paired photoreceptors. Fifteen lasers were placed on two adjacent walls, and paired with photoreceptors on the opposing two walls. This configuration allowed us to capture the participants' spatial location in two dimensions with a spatial resolution of one foot and a temporal resolution of one tenth of a second. Laser arrays and photoreceptors were placed at the bottom of the pegboard (1.1 m from the ground).

Variance in the resistances from the photoreceptors was monitored with a keyboard encoder (model: KeyWiz Eco). As light beams were interrupted by a participant's body, resistances in the photoreceptors dropped to zero, which the keyboard encoder then relayed to a PC as simulated keystrokes. Java software, written by the authors, monitored the virtual key states and handled a visual display, recorded a log of the participants' locations, and transmitted one of four sounds corresponding to the four object locations in the room. These audio cues were approximately one second in length, and were continuously played (looped) as long as the participant remained at the location. The sounds used were that of a dog barking, a cat meowing, a sheep bleating, and a rooster crowing, and all were within frequencies used for everyday speech. These sounds identified the locations so that each location, or "invisible object", was referred to throughout the experiment by the animal name associated with the sound (e.g., "Where was the cat?").

The medium and large spaces were sectioned off portions of the UCSB campus. The medium-sized space was a large, grassy area slightly elevated above the surrounding walkway. The large-sized space was a portion of a campus green, separated from the surrounding green by identical landmarks (flagged wooden dowels) on each corner. Tracking of user position in the outdoor spaces required a high-precision GPS unit; we used a Trimble AgGPS 114 model, designed for use in precision agriculture. In a thirty-eight hour field-test conducted by the authors, the root mean squared error (RMSE) for absolute distance deviation of the unit from the average was 0.55 meters. Ninety-five percent of all observations had an error less than 1.02 meters. This unit was used with excellent results in a navigation system for the blind (Loomis et al., 2005). By way of comparison, in a similar trial conducted by the authors, a consumer-grade GPS unit utilizing the MTK GPS chipset produced a GPS log with an RMSE of 1.6 meters, with 95% of all observations less than 2.7 meters from the mean. The Trimble AgGPS 114 unit used in the study was configured to output its position five times per second over serial cable to a laptop computer. Both the laptop and GPS unit were attached to a metal backpacking frame, and the complete weight of the backpack was approximately five pounds.

A computer program was written in Java to read position information from the device, convert the position to Universal Transverse Mercator (UTM) coordinates, and log the position and other context information related to the quality of fix (e.g., number of satellites used, dilution of precision values, and differential correction availability) to a file on the local disk. The software was also responsible for interpreting whether the participant was near enough to a waypoint to play the corresponding audio cue from the PC speaker. The position of the participant was logged to hard disk once per second.

The sizes of trigger sites were scaled to be proportionally equivalent between conditions. In the small search space, the interruption of two designated (x and y) lasers triggered the audio cue. In practice, the perceived size of this trigger was related to body size. Pilot testing placed the perceived trigger radius at approximately 0.46 meters. This value was used to scale the trigger area so that it would be proportionally equivalent at the larger spaces, and was set at 4.9 m^2 and 19.6 m^2 for the medium and large sized spaces, respectively. This resulted in a trigger area to total area for each object of approximately 1:50 at all scales. The spatial distribution of the trigger sites was designed to mirror, as closely as possible, the distribution used by Hill et al. (1993). In this way, although the size of the space increased, the arrangement of the trigger sites remained constant across conditions.

Following the task, participants indicated their estimates of the positions using a tripod-mounted digital compass (model: Coleman Digital Compass 814-672T). Additionally, participants in the small search space condition completed a post-task debriefing. The results of that briefing informed the development of a 5-item questionnaire used to calculate a strategic disposition index (SDI) that corresponds to the degree to which a person actively strategizes when wayfinding (Pingel 2012). Participants in these conditions additionally completed the 15-item Santa Barbara Sense of Direction Scale (SBSOD) questionnaire, shown to correlate well with overall environmental spatial ability (Hegarty et al., 2002). The SBSOD represents a mechanism to measure participants' self-assessment of their own sense of direction, and therefore a way to partially separate strategy from general performance on environmental spatial tasks.

PROCEDURE

Upon arrival for the study, participants indicated consent to participate and were read task instructions by the researcher. The key instruction for participants required them to "find and remember the locations of four invisible objects in the room, whose positions [were] marked with audio cues of animal sounds." They were then taken to a common start location ("Home") and instructed to indicate to the researcher when they felt they knew where the "animals" were. At this point, the researcher entered the space with the tripod-mounted compass, asked the participant to return to the start location, where participants were asked to point to the animals. The order was dictated by the researcher, and was chosen at random for each participant. Finally, participants completed both the SDI and SBSOD questionnaires, and indicated their age and sex.

DATA PROCESSING

The digital log produced by the Java software written for the small search space recorded the time, activity of each laser sensor (binary on or off), and the sound (if any) that was playing at that moment in a comma delimited text file, with ten records logged each second. The position of the participant was determined by taking the average of the activated sensors for each line entry in the log. For the outdoor space, GPS position and trigger activation was logged once per second. In all cases, any missing values were linearly interpolated. These logs provided a record of total time and total distance travelled.

To segment the data more meaningfully, we approached the problem in two ways: (1) we segmented the tracks according to the likely goal to which movement was directed, and (2) we classified the overall type of systematic search by the participant, if any. Since the task required participants to both find and remember the locations of objects—two conceptually distinct directives—we developed an automated algorithm to classify each segment of a participant's track into one of three types of movement: search, localization, and reinforcement. *Search* applied to track segments in which the participant had goal directed movement to an object not previously found. *Localization* applied to track segments in which the participant attempted to finely fix the location of the object in the space through repeated sequential movements to the same trigger site. *Reinforcement* corresponded to track segments in which the participant returned to a previously found object, and coincides with Tellevik's (1992) "reference-point" strategy and Hill et al.'s (1993) "object-to-object" strategy.

Visits to objects were recorded directly by the logging software based on the initiation of the audio cue. Localization was distinguished by the observation of repeated movement to the same object within a specified amount of time (5 seconds), and reinforcement was defined by movement to a previously found object within a specified distance proportional to the mean distance between objects for that sized space. If the participant had previously found all four objects, any subsequent movement between objects (i.e., movement not classified as localization) was also classified as reinforcement. Any movement not classified by the above criteria was classified as search. Movement between two previously found objects could therefore be either classified as search or reinforcement, depending on how direct the movement was. Most reinforcement movement was of the kind shown in Figure 3c: manifestly direct, and therefore short returns. Indirect movement between previously found objects (e.g., some legs in the gridline search shown in Figure 3b) could have been classified as search if the distance between objects was excessively lengthy. This, however, was not an incorrect interpretation in most cases given that the algorithm correctly interpreted the longer return visit (a function of a visit to the edge of the space) as the result of search rather than reinforcement behavior. Animations from the output of the classification were used to iteratively refine the algorithm based on visual inspection. This method was less likely prone to human error and allowed for a more objective and easily repeatable type of classification.

Three external judges were asked to examine the final animations and to code for presence/absence of two different search strategies: (1) a perimeter search, defined as "a systematic search of the outside edge of the space, consisting of at least three consecutive edges/walls," and (2) a gridline search, defined as "a systematic search consisting of a series of parallel transects covering all or part of the space." Fleiss's kappa, which indicates level of agreement, and ranges from -1 (perfect disagreement) to 1 (perfect agreement) was 0.88 for perimeter coding among the three judges, and 0.83 for gridline coding. A participant was ultimately coded as having a perimeter or gridline search present if two of three judges agreed. Examples of the tracks of four participants are shown in Figure 3.

RESULTS

Given the difference in tracking technology between indoor and outdoor conditions, we felt it important to apply some simple diagnostics to the dataset to ensure measures of behavior and performance met expectations. As one would expect, mean total track length increased monotonically with scale, with a Pearson's correlation of $r(46) = 0.47$, $p < 0.001$. This was not the case with total time travelled, as participants in the large-scale condition moved much faster ($M = 0.94$ m/s, $SD = 0.16$) than did participants in either the small ($M = 0.60$, $SD = 0.10$) or medium-scale conditions ($M = 0.64$, $SD = 0.12$). The difference in speed was significant according to a general linear regression model using the square root of the area as the predictor, unstandardized $\beta = 0.01$, $t(46) = 7.34$, $p < 0.001$. As a result, all further analysis is presented in terms

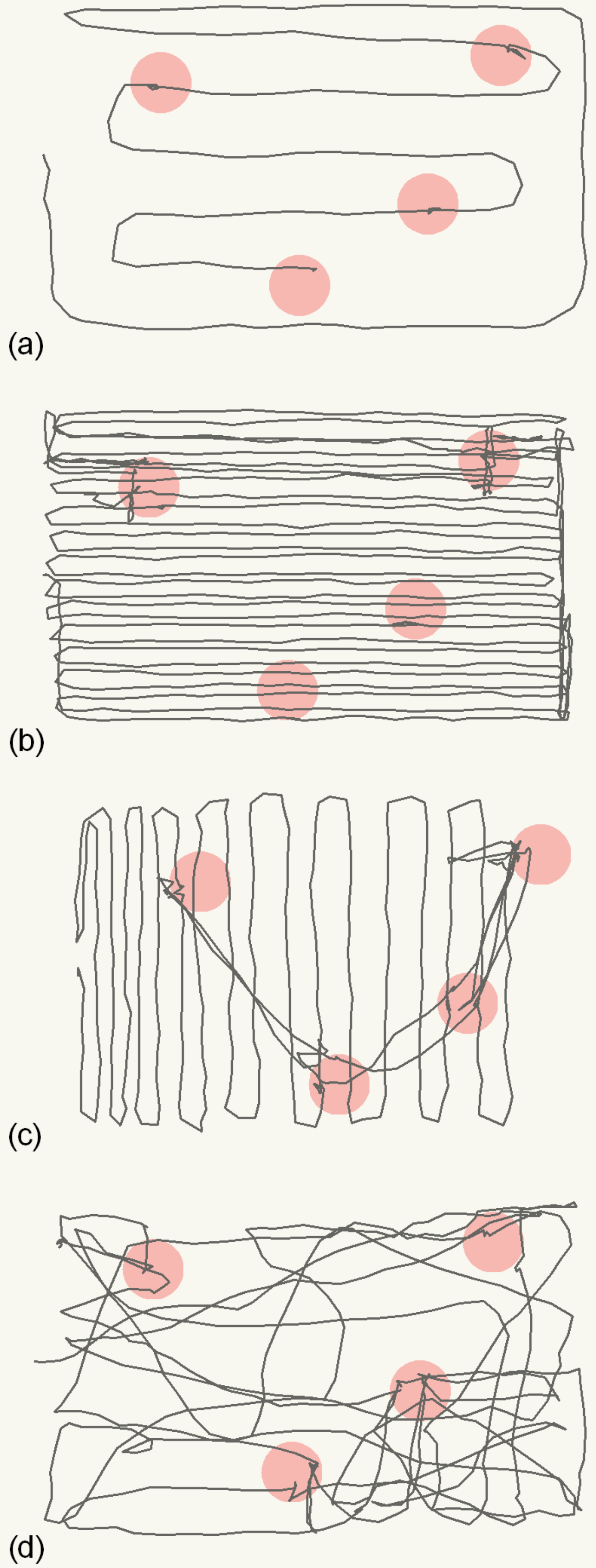

Figure 3: Images of complete search tracks for four individuals with trigger sites shaded. Figures 3a to 3c show evidence of systematic, gridline searching, while Figure 3d does not.

	small	medium	large
total distance (m)	143.5 (61.4)	203.9 (96.9)	267.8 (120.8)
total time (s)	240.4 (96.9)	319.8 (148.5)	286.6 (129.3)
mean speed (m/s)	0.60 (0.10)	0.64 (0.12)	0.94 (0.16)
gridline searches (%)	21.5	56.2	66.7
perimeter searches (%)	85.7	12.5	16.7
search distance (%)	52.5 (23.3)	67.7 (16.6)	77.4 (16.4)
localization distance (%)	11.2 (8.1)	15.2 (6.9)	14.3 (7.0)
reinforcement distance (%)	36.3 (19.1)	17.2 (13.5)	8.3 (14.5)
search distance (m)	68.0 (35.2)	141.7 (77.7)	200.9 (88.5)
localization distance (m)	18.0 (16.3)	27.9 (11.6)	35.3 (16.0)
reinforcement distance (m)	57.6 (41.2)	34.3 (28.4)	31.6 (62.1)
mean absolute pointing error	24.8 (18.55)	10.1 (6.5)	9.9 (3.8)

Table 2: Results (mean and standard deviation) by size condition. Larger spaces featured more gridline searches, and participants tended to spend more time searching for and less time reinforcing knowledge of the locations of objects as the size of the space increased.

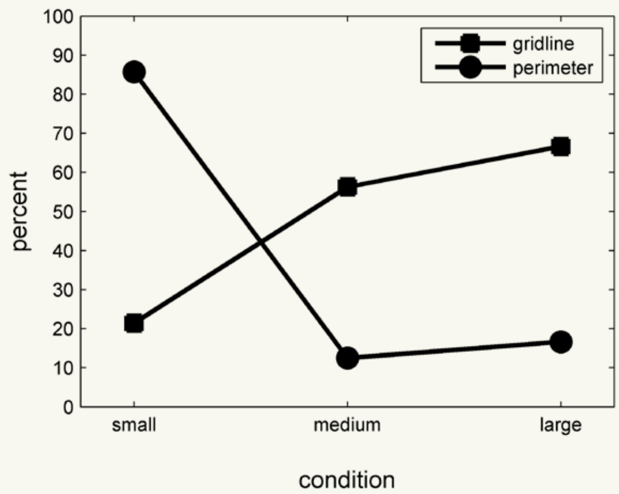

Figure 4: Perimeter searches were common in the small search space, but much rarer in the larger space. Gridline search rates increased monotonically with the size of the search condition.

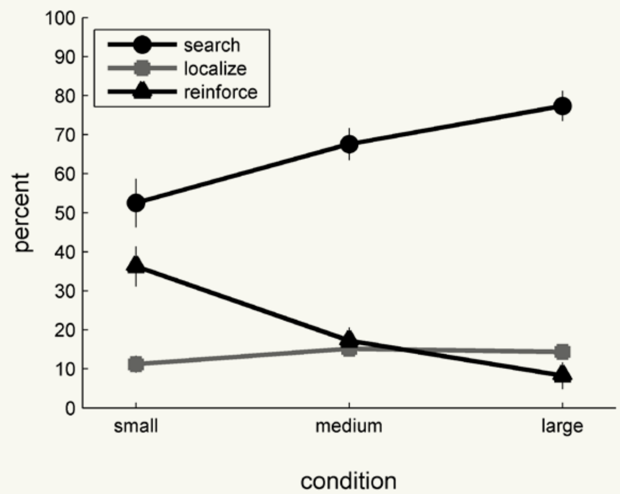

Figure 5: Mean distance as a percentage of overall track length spent on search increased with increasing size of the space, while mean distance (%) spent on reinforcement decreased. Localization showed a moderate, statistically insignificant increase.

of distance, rather than time. Complete descriptive statistics by scale condition are presented in Table 2.

Mean absolute pointing error diminished monotonically as the size of the search space increased. Mean error was 24.8 degrees at the smallest scale, 10.1 degrees at the medium scale, and 9.9 degrees at the largest scale. These differences were statistically significant, $\beta = -0.50$, $t\,(46) = 3.31$, $p < 0.002$.

Scale proved to have a strong impact on the type of search strategy that participants used. The propensity to search using a gridline strategy increased as the size of the space increased: in the small space, 21.5% of individuals used a gridline search, but the rate increased to 56.2% for the medium-sized space, and 66.7% for the large-sized space (Figure 4). The difference was significant according to logistic regression where a binary value (0 = no gridline; 1 = gridline) was used as the dependent variable, and the square root of the area was used as the predictor ($\beta = 0.07$, $t\,(46) = 2.34$, $p = 0.02$). Perimeter searches showed the inverse pattern, as small-sized spaces were more likely to be searched via perimeter and large-sized spaces were less likely to be searched in this way (β = -0.12, $t(46) = 3.19$, $p = 0.001$).

In addition to influencing how individuals searched, scale played an important role in the composition of wayfinding (i.e., the amount of distance participants spent *searching*, *localizing*, or *reinforcing*) during the task (Figure 5). While the percent of distance spent *localizing* remained largely unchanged, participants spent more distance *searching* and less distance *reinforcing* as the size of space increased. Search percentage was 52.5% in the small space, but increased to 67.7% in the medium-sized space, and 77.4% in the largest space; a similar decrease was noted for reinforcement behavior (see Table 2). Linear regression indicated the relationship was statistically significant for both search (β = 0.90, $t\,(46) = 3.67$, $p < 0.001$) and reinforcement (β = -1.00, $t\,(46) = 4.7$, $p < 0.001$).

The addition of sex to the preceding regression models did not significantly improve predictive performance, indicating that there were no detectable sex differences in these strategic measures. Similarly, although there were differences observed between conditions for mean absolute pointing error (β = -0.50, $t\,(46) = 3.31$, $p = 0.002$), sex differences were not significant when added to the model (β = -4.70, $t\,(45) = 1.42$, $p = 0.16$).

Correlations between SBSOD score (a self-report measure of environmental spatial ability, Hegarty et al. 2002) and SDI score (a self-report measure of strategic disposition in wayfinding contexts, Pingel 2012) did not reach statistical significance. However, while correlations between SBSOD and search type were positive ($r = 0.06$ for gridline, 0.05 for perimeter search), correlations between SDI and search type were negative ($r = -0.12$ for gridline, -0.05 for perimeter search) indicating that self-described strategists were less likely to use systematic search.

An explanation for these results may rest with the overall lack of improved performance between systematic searchers and non-systematic searchers. Gridline searchers did not significantly improve mean absolute pointing error (β = -3.80, $t\,(45) = 1.08$, $p = 0.029$) although the beta coefficient was in the expected direction (Hill et al. 1993). More importantly, gridline searching did not reduce overall search distance (total distance × search percentage). Regression analysis confirms that gridline searchers actually spent *more* distance searching than non-gridline searchers in a model that included presence / absence of gridline search and the square root of the area of the space as independent variables (gridline β = 46.9, $t\,(45) = 4.19$, $p = 0.03$; Figure 6). Mean search distance was longer for gridline searchers, but variability was slightly lower in the small and medium-sized spaces and slightly higher in the large-sized space (Figure 7). This provides some evidence that systematic searching may be an attempt to limit the variability of the result rather than to reduce the mean distance travelled.

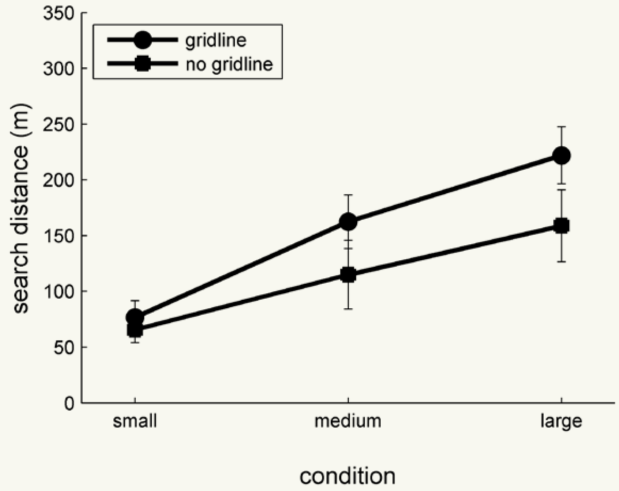

Figure 6: Mean search distance for gridline searchers was longer than non-gridline searchers for all conditions.

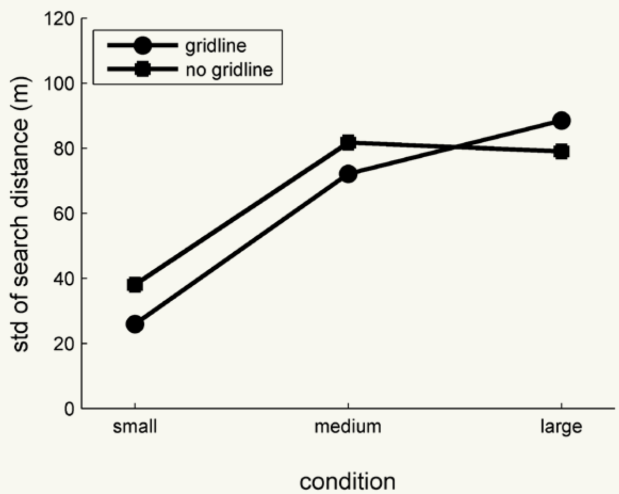

Figure 7: In small and medium-sized spaces, but not large spaces, gridline searchers had reduced variability in search distance.

DISCUSSION

The experiment detailed above extended previous studies on search strategy made by Tellevik (1992), Hill et al. (1993), and Gaunet and Thinus-Blanc (1996). In this case, however, searches were conducted by non-blindfolded, sighted participants who looked for "invisible" objects in spaces approximately 25 m², 250 m², and 1,000 m². Participants in the small space condition showed search pattern distributions somewhat similar to Tellevik, in that perimeter searches were more common than gridline searches. Gridline searchers in particular were notably higher than Hill et al.'s (1993) best performers. We submit that the difference in gridline search rates observed between our study and Hill et al.'s stems from the ease with which vision enables the searcher to coordinate their search in space (Thinus-Blanc and Gaunet 1997).

Our results generally contradict Tellevik's explanation that the drop in systematic search behavior between successive trials that he observed can be attributed to a familiarity with the space on the second encounter. Were this true, one would expect sighted individuals in similar circumstances to rarely use perimeter or gridline searches. In our experiment, in an equivalently-sized space, perimeter searches were very common, and gridline searches were hardly rare. Since our participants could apprehend the space immediately with vision, these systematic searches had no impact on learning the configuration of the space. A more likely explanation of Tellevik's results is that participants shifted their focus from *finding* to *remembering* the locations of the objects.

A similarly important finding is that the type of search is a poor predictor of either pointing performance or search distance. A more useful predictor was the amount of distance spent on *reinforcement* rather than *searching* during the task—a value that corresponds with Tellevik's *reference-point* strategy, or Hill et al.'s *object-to-object* strategy. In effect, the searcher must choose the degree to which they focus on the "find" versus the "remember the locations of" instruction, while at the same time reducing the total amount of time, distance, or effort spent on the task. Just as in the well-described speed-accuracy tradeoff observed in other types of psychological testing, the searcher attempts to balance many criteria to their own satisfaction.

In this sense, strategy is neither equivalent to performance, nor to systematic search. In this study, participants who used the most systematic of searches we coded for—the gridline search—took longer to search the space than those who did not. This counterintuitive result indicates that the drive for systematization is not necessarily about improving the overall mean result, but is related to some other factor—perhaps aspects of personality or risk aversion. This perspective is in accord with the observation that SDI score—a self-report measure of strategic disposition—was not a significant predictor of search strategy. SDI speaks to the degree to which a person conditionally reasons about the impact of their behavior on variables that affect the achievement of desired ends, but says nothing about the particular plans or methods that the strategist might use. In many strategic games, an introduced degree of randomness can be a better strategy than an entirely systematic one, and famous strategists have differed quite markedly in the degree of planning and orientation to risk inherent in their strategies.

Reducing the mean (or median) cost of the search is clearly important to the searcher. The systematic ways that have been devised to conduct a search largely focus on segmentation (dividing the work into manageable pieces) and the prevention of overly-redundant effort. A gridline or parallel search is useful, in large part, because it is a simple pattern that prevents the space from being searched unevenly. As important, though, is the variability of cost measure enabled by a systematic search. Systematic search may well reduce the mean cost, but it also makes the cost more predictable. In searches where lives are at stake, the reduction of variance may be paramount, for the searchers may not care so much what the mean solution time is as much as they care that it likely does not exceed a given value. While central tendency and dispersion often vary together for these types of costs, it is helpful to recognize that the uncertainty associated with large variability is often considered a cost of its own, and as such its reduction is a direct target of strategic behavior.

Finally, as the size of the space became larger, participants increasingly focused on search rather than reinforcement. The shape of the curve describing the change (Figure 5) is also curvilinear, suggesting that—as Tobler (1993) observed in a different sort of transportation problem—the cost of overcoming distance increases, but at a decreasing rate. At larger sizes of space, travel costs are perceived as higher to the degree that observed behavior changes qualitatively. Since all searches took place at the vista psychological category of scale—a size of space that Montello (1993) described as being capable of apprehension without appreciable locomotion—this suggests that kinds of spaces may have finer gradations than are commonly appreciated. In particular, it suggests that the costs of traversing room-sized spaces are qualitatively different than the costs of traversing town-square, or campus green-sized spaces.

One limitation of the study was its somewhat small sample size. In our case, the effect size of scale on strategic variables was large enough such that significant differences were apparent between conditions. However, we did not detect significant differences for sex, environmental spatial ability, and strategic disposition in some cases in which they might have been expected. As a result, we can only comment that there were no observable differences for these variables, and hope that our results may provide better upper bound estimates for effect sizes in future work on this topic.

A second limitation of the study involved the control of landmarks between conditions. The small space was relatively featureless, while in the outdoor spaces, participants had a full view of surrounding landmarks. This was unavoidable given the infeasibility of constructing such a large, featureless space, and blindfolds would have artificially limited the ability of participants to coordinate a search. In any case, post-task debriefing of participants in the indoor space condition revealed that they had no difficulty constructing landmarks from otherwise trivial imperfections (e.g., a scratch on the floor) or in maintaining orientation within the room. For this reason, we believe it unlikely that differences in landmark availability significantly influenced the results.

CONCLUSIONS

In search-based wayfinding problems, the size or extent of the space to be searched has a profound effect on the types of strategies used to explore the space. In this experiment, in which participants were asked to find and remember the location of four positions in an empty space marked only with audio cues, small (~ $20m^2$) sized spaces elicited relatively less systematic, more random spatial searches and relatively more effort spent on reinforcing the relative positions of objects via repeated object-to-object visits. Participants searching larger spaces (~250 m^2 and ~1000 m^2) rarely used object-to-object visits, but much more frequently used gridline search patterns to explore the space.

Since search is an integral part of wayfinding, whether by navigating to a previously unknown destination or through evaluating potential routes between waypoints, understanding how scale can impact the strategies that individuals use is a key requirement. Our results suggest that wayfinding preferences commonly integrated into navigation software should be designed with scale in mind. For instance, a preference for simplest paths—where absolute performance in terms of time or distance is sacrificed in order to reduce the complexity of the route—may be more applicable at smaller spatial extents than larger ones. This is because at smaller scales, small sacrifices of time or distance may be discounted, while at larger scales, the costs of traversing space may be viewed as relatively higher.

Finally, these results suggest that while different scales of spatial problems—figural, vista, environmental, and geographical—may indeed elicit different kinds of thinking, the categories themselves are somewhat flexible. Our results indicate that individuals strategize about room scale spaces very differently than campus-green or town-square sized spaces, and yet both of these exist at the vista scale. While it is possible that differences in indoor vs. outdoor administration of the experiment caused the differences, even this would require some amendment to Montello's (1993) categorization of the psychology of scale. Ultimately, a multidimensional taxonomy of the kinds of the changes in the quality of spatial thinking we find at different scales may prove the most useful in delineating the most appropriate divisions of a psychology of scale.

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Looking at the Big Picture: Adapting Film Theory to Examine Map Form, Meaning, and Aesthetic

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Film and maps have much more in common than is often believed. In this paper, it is argued that film offers cartographers many concepts that can be used to better understand map form, aesthetics, and meaning. After reviewing these concepts as taught in film studies and originally formulated by Kenneth Burke, this article explores how these concepts can be applied by cartographers in their map design and by map critics. Several examples of adapting these theories to understand maps are provided. The paper concludes by arguing that cartographers can only benefit by more whole-heartedly embracing and adapting film theory concepts and methods. Doing so will likely result in clearer communication, storytelling, and argumentation, as well as offer a more nuanced method for determining what makes certain maps memorable.

KEYWORDS: map form; map meaning; map aesthetics; film theory

INTRODUCTION

At first glance, it may seem that the relationship between cinema and traditional cartography is tenuous at best. After all, until recently maps were largely represented on paper—a static medium to say the least—and at its core, cinema is all about "moving pictures." Obviously, it is easier to see a connection between animated cartography and cinema (for examples, see Harrower 2004 and Tobler 1970). Even when maps are animated, however, one might opine that the goals of filmmaking and mapmaking are largely incongruent. The overarching purpose of this paper is to convince you that such assumptions are likely naïve; the connections between film and mapmaking are numerous and there is much that cartographers might learn from looking at this field. The following pages set out to achieve two specific goals: (1) to explore how certain film theory perspectives might be usefully adapted to better conceptualize map form, aesthetic, and meaning; and (2) to begin the process of articulating the concept of map form based on existing literature found outside the discipline of cartography.

This paper is an exploratory exercise, but one that I feel has the potential to help the cartographic community better address a variety of questions. First, in recent years interest in map aesthetics has resurfaced (Buckley et al. 2012; McCleary 2012). As will be shown shortly, in film studies the concept of aesthetic is a component of film style (i.e., eloquence), which in turn is dependent on film form. I believe that until cartography better problematizes what is meant by map form, the discipline will never be able to sufficiently address what is meant by map aesthetics. Second, as with maps, not all films are designed to achieve the same goals. Both cinema and cartography can serve multiple communicative purposes, including explanation, narration, and argumentation. Achieving these purposes is done through the manipulation of form. Changes in form impact how effective a map is at achieving its purpose with an intended audience. Finally, meaning is far more nuanced in film studies than it is in general cartography. As I will argue, whereas cartographers tend to focus on achieving particular referential and explicit meanings, we might learn a lot by adopting film theory's use of implicit and symptomatic meaning into our design and critiques of maps.

CINEMA : FILM :: CARTOGRAPHY : MAP

Before continuing, a handful of terms need to be clearly defined. *Cinema* refers to the science and art of filmmaking. Cinema does not represent a film, but rather the process of designing, producing, distributing, and promoting films. Similarly, *cartography* in this paper refers not to a map itself but to the process of designing, producing, distributing, and promoting maps. *Film* as used in the rest of this paper represents a motion-picture product. Granted, many "films" these days are not actually produced on film, but rather digitally. However, the moniker is still used here and includes all motion pictures produced on film, VHS, or digitally. Assuming many readers of this piece are professional cartographers, and therefore have very individualized and nuanced definitions of what a map is, it is important to note that for the rest of this paper a *map* is simply defined as the end product of cartography: a visual communication of spatial information.

THE MYRIAD CONNECTIONS BETWEEN CINEMA AND CARTOGRAPHY

Though not garnering as much attention as the linkages between cartography and graphic design (or Brad Pitt and Angelina Jolie, for that matter), cinema and cartography have an established on-again, off-again history together. The relationship between the two can be broadly broken down into three areas: (1) rhetoric and persuasion; (2) conceptual and technological developments; and (3) theoretical conceptualizations of how films and maps (re) present space.

1) RHETORIC AND PERSUASION

Beginning in the early twentieth century, those in positions of social power quickly began to realize the ability of cinema to influence audiences' perceptions of and feelings about the world. In the 1930s, Germany created the first television network and a variety of films to help promote Nazi ideology and cultural values (Kloft 1999). During World War Two, Western academics began fearing that cartography could be used by the Germans to do the same. In fact, Germany did actively produce atlases and maps for propagandist purposes to convince both those in Germany and those residing overseas of Germany's just cause for war (Herb 1989; Mayer 1976; Pickles 1992; Wirsing 1941). Speier (1941) was arguably the first to note the relationship between persuasive mapping and filmmaking, noting that "entirely new possibilities in the use of maps for political propaganda are revealed by the [use of] film. The German propagandists have realized [this]…" Due to their dramatic and appealing nature, Speier saw moving-picture maps as an area ripe for propagandist manipulation. Ironically, though many were paranoid about German use of animated propaganda maps, one of the most renowned examples of such a map was produced by Disney during World War Two (Harrower 2004).

Boggs (1947) was next to dramatically argue that, as in films, "maps may be true in every detail, but in their omissions and their perverse emphases they may be socially poisonous—as chlorine by itself is a poisonous gas but an essential element in common salt" (471). Boggs was, in very dramatic fashion, making the connection that both films and maps are fake—neither show reality, only a director's or cartographer's (re)presentation of reality. What is left off the map, as Boggs feared, often has more impact on shaping people's perspectives than what is left on it.

Recently, I examined persuasive maps found online, many of which incorporate film-like animation (Muehlenhaus 2014). One example, an Israeli Defense Forces YouTube video map, so nearly replicates particular scenes from the film Starship Troopers (Verhoeven 1997) that one might feel a citation is in order! In the video, entitled "What Gives Israel the Right to Defend Itself?" the IDF omits a great amount of contextual information in its review of the Gaza crisis (Figure 1). The map is part of a larger "just war" discourse (Flint & Falah 2004), using sound effects, voiced-over narration, and a presentation of one-sided violence to justify Israel's actions in Gaza. Now that films are easier than ever to produce and distribute, I surmise that such persuasive film-maps will become increasingly common.

2) CONCEPTUAL AND TECHNOLOGICAL CONNECTIONS

Film's most direct influence on cartographic thought and theory is arguably in the realm of visual variables and

Figure 1: Top two images: screen captures from the Israeli Defense Forces YouTube video entitled What Gives Israel the Right to Defend Itself? *Available at: youtu.be/LxX6f5R4-3E. Bottom two images: screen captures from several propaganda news clips in the film* Starship Troopers *(Verhoeven 1997) with very similar looking animated maps and a* Would You Like to Know More *button.*

technological conceptualization. Cartographic design, indeed nearly all visual information design, depends on the intelligent use of visual variables. Bertin (1983) was the first to specifically outline the core visual variables for use in static information graphics. His work has greatly influenced cartography ever since. Bertin ignored animation at the expense of static graphic variables partly because he believed that it was merely a single variable—and one that was too overpowering to be of much use in information design (MacEachren 1995, 278).

As digital cartography made map animation easier, DiBiase et al. (1992) argued that Bertin was incorrect: a review of cinema demonstrated that films presented at least three new visual variables: *duration, rate of change,* and *order.* Soon thereafter, MacEachren (1995, 281–287) proposed three additional variables: *display date, frequency,* and *synchronization*. As maps have increasingly shifted from paper to interactive screens, the visual variables that cinema has illuminated for mapmakers have become increasingly important.

Beyond cinema's contribution of visual variables to cartography, Caquard (2009) has pointed out that cinema has largely foreshadowed technological developments in cartography. In fact, everything from real-time data animation (*Dr. Strangelove*), slippy-maps (*Goldfinger*), Google Earth (*Casablanca*), and global to inside-building zoom capabilities (*Enemy of the State*) were foreshadowed by cinema years, even decades, before cartographers created similar maps. Caquard provides numerous reasons why Hollywood "cinemaps" highlighted cutting-edge maps before academic cartographers could, including the fact that filmmakers did not need to make real, functioning maps, and that cinemaps do not have to be truly interactive. Regardless of the reasons, Caquard's work demonstrates that cinema has played an intrinsic and large role in guiding cartographic theory and development.

3) THEORETICAL CONCEPTUALIZATIONS OF HOW FILMS AND MAPS (RE)PRESENT SPACE

The third area of investigation between cinema and cartography is more theoretical—the exploration of films as maps. Castro (2006), for example, has outlined how a trove of French documentary films shot around the world in the early twentieth century are best defined and analyzed as an atlas. Castro notes that just like maps, documentary films—or collections of documentary films sequencing their content like the pages of an atlas (e.g., *Cosmos*)—are strongly informed and contextualized within the imperialist and societal discourses of their times (Shohat & Stam 1994, 100–136). In later work, Castro (2009) expands upon her earlier work and shows that films also act as maps through their panoramic shots and aerial views. Films visually communicate spatial information about places.

In his comprehensive effort to evaluate film from a cartographic perspective, Conley (2007) more explicitly connects cinema and cartography. He ties films and maps together by viewing them as two sides of the same coin—rhetorical, ideological tools meant to shape how people perceive the world:

> ***"Maps and films might be said to be strangely coextensive. Of vastly different historical formation, cinema and cartography draw on many of the same resources and virtues of the languages that inform their creation. A film can be understood in a broad sense to be a 'map' that plots and colonizes the imagination of the public it is said to 'invent' and, as a result, to seek to control. A film, like a topographic projection, can be understood as an image that locates and patterns the imagination of its spectators. When it takes hold, a film encourages its public to think of the world in concert with its own articulation of space. The same could be said for the fascination that maps have elicited for their readers since the advent of print-culture or even long before. Both maps and films are powerful ideological tools that work in consort with each other." (1–2)***

In other words, both filmmakers and mapmakers know that what they are producing is not reality. What both often tend to deemphasize, or conveniently deny, is that the visual representations they are producing inevitably, and irrevocably, help *shape reality* for viewers. All films and maps create, or at minimum reify, false, ideological-based realities.

Delving even further into the philosophical connections between cinema and cartography, Lukinbeal (2010) uses Pickles' (2004) concept of the "cartographic paradox" to argue that cinema and cartography are ideological technologies facilitating two contradictory types of spatial hegemony. Film acts as the ultimate tool for making linear perspective "natural" and ontologically pure. Linear perspective is just that: one invented, artificial view of the world (Dondis 1973). But, since the Renaissance, this art method has become synonymous with reality for many people. Though generally accepted by the public at large, work in human perception has shown that there is no visual reality—everything we "see" is interpreted and frequently interpreted poorly (Hoffman 1998). At the other extreme, cartographers have made the projection of the Earth ontologically accepted as well (i.e., the God's-eye trick of projecting what is impossible to see all at once, explained in Roberts et al. [1995]). Neither images shown in perspective (e.g., a fade-out sequence of a sunset) nor projection (e.g., the world in a Web Mercator) are real. Both are ideologically hegemonic representations of reality that, through repetition and exposure (Battersby 2009), as well as dominant societal discourse, are now largely accepted as real by viewers (Lukinbeal 2010).

Obviously, the connections between cinema and cartography are deep. Film and maps both do the same thing: they give people meaning (e.g., feelings, facts, thoughts, or ideas) about real and imaginary places. They use similar methods to achieve their goals. Films use props, sets, lighting, framed shots, and differently distorted lenses to represent places. Cartographers use data, symbols, visual hierarchy, layouts, and differently distorted projections.

In this paper, I propose a novel idea, similar to the aforementioned links between cinema and cartography: if cartographic theory can be used to analyze films, then it is probable that cinematic and form theory can be used to analyze maps. One area that remains a conundrum for cartographers is map aesthetics. What makes a map beautiful, stylish, or timeless? How can we better determine which maps are of exceptional quality and which are "B-film" material. The answers to these questions may lie in further developing the concept of map form, eloquence, and meaning. These are all concepts that film experts use when designing, critiquing, and looking for meaning in films.

Below, I will first review the key concepts of film form and meaning, followed by a discussion of how these concepts can be applied to cartography and map design. The paper concludes with the idea that conceptualizing map form and meaning using a more film studies-like method could lead to the development of map critiques, evaluations, and potentially genres, which are not based on how data are represented on a map but on the form of a map itself.

THE CONCEPT OF FILM FORM

> ***"Form is the creation of an appetite in the mind of an auditor, and the adequate satisfying of that appetite" (Burke 1968, 31).***

All types of media have what is called "form." However, film form is so important for effective cinematic communication that it has been and remains a central focus in film analysis. What is form? Bordwell (2004, 49) notes that broadly form is best thought of as "the overall system of relations that we can perceive among the elements in the whole film." Thus, it is simply the structure containing all components of film communication. Film form is *everything* that a film contains, including such diverse elements as plots, plot-twists, narration, soundtracks, characters, credits, points-of-view shots, special effects, scenes, and all content. Everything. Crucially, form includes the *relationships* (i.e., symbiosis) between all film elements. Form is not merely a collection of elements; form is the entire system within which these elements interact with one another. It is a holistic structure.

FORM ELOQUENCE

A film's style is a manifestation of its form. Style has nothing to do with the perceiver; it is audience-independent. A film's style is completely fabricated and created by the director. Style is the result of the filmmaking process, including all decisions made regarding how dialog, camera movements and angles, narrative ordering, credit and title fonts, sub-plots, minor characters, costuming, make-up, product placements, visual cues, and pace of story interact and fit with one another. Style is a vague and loaded term, imbued with many different meanings. Therefore, throughout the rest of this article the concept of style will be substituted with Burke's (1968) more refined concept of "eloquence."

The eloquence of a film's form is what determines whether a piece of art will be satisfying and memorable. All films have form but some are more eloquently formed than others. Slightly modifying Burke's (1968, 37) original definition of eloquence as it pertains to form in the arts, we can say that eloquence is "the minimization of [audience] interest in fact" so that *how* the facts are presented becomes key to understanding. If a film has eloquent form, all its composite parts work well together and affect viewers emotionally. It is films with superb form that people enjoy viewing many times over, for these films do more than provide information: they make an audience feel immersed in, indeed consumed by, a description, a narrative, or an argument.

In other words, eloquence of form has little to do with the individual film elements or content being presented, and everything to do with how all of the elements work together to arouse and fulfill audience desire (Burke 1968, 124). Content (i.e., information) is certainly a component of form, but it loses its narrative power after one showing (e.g., how many times can someone sit through *An Inconvenient Truth* and maintain peak interest?). After information has been viewed once, most of its enticement for viewers is spent (Burke 1968). Eloquence is more than information; it is about presentation. As Burke notes, it is all about giving the audience a meaningful taste of something that makes them want to come back and experience a piece of art again (34–35). Eloquence makes a lasting impression and impact on viewers that does not grow old quickly.

Eloquence itself can be broken down into two broad categories: mannered and styled (Burke 1968, 165–167). Films featuring *mannered eloquence* are more formalized and syllogistic. Mystery films, for example, tend to follow exactly the same sequences. They start with a crime; an investigation begins; several subplots develop and a handful of characters are suspected; slowly but surely all suspects are ruled out until the case is resolved. Though the audience knows how the film is going to unfold—often before they even begin viewing it—the film itself maintains eloquence through the introduction of surprising and suspenseful plot elements, and by not providing resolution until the end, maintaining an appetite in the audience.

Contrarily, *styled eloquence* tends to break away from conventional or formal sequences. It may present a variety of film elements that at first seem distinct and diverse but when recalled and contextualized within the entirety of the film, they coalesce together to help viewers make meaning. Perhaps there is no better example of this than the film *2001: A Space Odyssey* (Kubrick 1968). One reason this film is considered a classic is due to its styled and unpredictable form. The first twenty minutes of the film have no dialog, merely monkey-like creatures slaughtering pig-like creatures. This then cuts away to scenes on space stations floating around Earth and a formal meeting on the lunar surface. One hour into the film, the audience is suddenly introduced to, arguably, the main characters on a spacecraft approaching Jupiter. The film ends with an indecipherable, phantasmagoric lava-lamp sequence and scenes of the main character aging before presumably turning into a floating fetus in space overlooking the planet Earth (see Figure 2). The film is completely styled, following no playbook or genre. In the end, an appetite is created and it is up to members of the audience to create resolutions and meaning themselves. Styled form is what helped make this film a classic.

There are benefits and drawbacks to both mannered and styled form. The benefit of mannered eloquence in film is that it tends to induce within viewers a psychology of power over what is being viewed; the form is conventional and easy to predict (Burke 1968, 167). However, mannered eloquence also presents a danger of monotony. Unless something distinct is introduced in the form—a unique plot twist, for example—viewers may not become as emotionally

Figure 2: Top to bottom: four chronological scenes from the beginning to the end of the film, 2001: A Space Odyssey *(Kubrick 1968). The film's form offers anything but mannered eloquence.*

involved or accurately perceive the ideology of a film. For example, how many standard romantic comedies can one see before becoming completely disinterested in finding meaning from them? The meanings of such films are almost expected to be cliché, and therefore people generally do not absorb much meaning from them.

Styled eloquence is often far more complex and interesting for viewers, particularly when it comes to finding meaning in an art form. The downside of styled eloquence is that it runs the risk of diffusing the communication of a film to an extent that a director's desired meaning, or main point, is completely lost. The film *2001: A Space Odyssey* has resulted in an inordinate number of hypotheses looking for deeper meaning. Perhaps, as is sometimes the case with art, the form itself was merely meant to provoke thought—there was no intent to foster a specific meaning. However, meaning is created and constricted by form, and the styled eloquence of this film has obviously resulted in a breadth of idiosyncratic perceptions of what the film is "really" about.

A viewer's interpretation and appreciation of a film is still very much a cognitive process. People will interpret films differently based on their previous experiences, beliefs, cultural traits, and current moods. As occurs with those reading maps, film viewers have formal expectations about the form that films should take. When these expectations are not met, viewers will either become excited or agitated. Also, there are film conventions and expectations to adhere to; one who goes against the grain too much risks becoming a pariah. On the other hand, if successful, they could become the next Stanley Kubrick or Fritz Lang. Determining which type of eloquence to lean toward—mannered or styled—is always a difficult but fundamental task for any filmmaker developing a new project.

FILM FORM AND INTERPRETATION

As they begin viewing a film, audiences start looking for patterns that will allow them to create expectations about its form. Effective form gets an audience involved: "You as a viewer or listener don't simply let the parts [of a film] parade past you. You enter into an active participation with them, creating and readjusting expectations as the pattern develops" (Bordwell & Thompson 2004, 51). Form impacts film viewing mostly because it creates the impression that everything is there; you will not need to look outside of the film to understand the information being presented.

Figure 3: The characters introduced in the first scene of Pulp Fiction *(top; Tarantino 1994) are never referred to again until the last scene (bottom), bringing the audience resolution.*

Thus, the better the elements of a film interact with one another, refer to one another, mimic one another, and complement one another, the easier and generally more enjoyable film interpretation will be. For example, people expect prominent characters from early in a film to appear again at some point. If characters are introduced in detail and never again appear, film viewers will be confused, if not downright disappointed. People look for resolution. A great example of whetting people's appetites is found in *Pulp Fiction* (Tarantino 1994). The film starts with a couple contemplating burgling a diner and cuts away as soon as they begin the process. For over two hours the movie continues by introducing numerous characters and plots in a non-chronological fashion. Though most in the audience do not realize it, viewers are immediately looking for resolution: what did the first scene have to do with the movie? The answer only comes at the very end when the film cuts back to the diner (Figure 3). The audience's appetite, created by cutting away at the beginning of the film, is satiated.

Audiences also tend to enjoy motifs—dominant and repetitive themes throughout films—that help them tie different film elements and scenes together. In film, this is often done through repetitive dialogue. In *The Big Lebowski*, the main character sees President George H. W. Bush say "This aggression will not stand," on a television in the background. Throughout the rest of the film the line is repeated. In *Clerks,* the line "I'm not even supposed to be here today!" is repeated throughout the film to tie numerous, erstwhile scenes together. The effective repetition of motifs can also be used to better help audiences pick up on implicit meanings. *District 9* is a film that is explicitly about aliens being treated as second- or third-class citizens. However, through derogatory and pejorative language toward the aliens that mimics that of racist America and South African apartheid, implicit meanings can be made between the aliens in the movie and the treatment of undocumented immigrants and minorities today.

FORM AND MEANING

As with maps, the main point of all films is to communicate—be it a narrative, an argument, or description broadly. In essence, it is often the goal of the filmmaker to construct a piece of art that conveys a desired meaning to those viewing it. Film viewers are constantly looking for larger significance, suggestions, and discrepancies in what is being presented. Though the director of a film cannot control what or how people find meanings in a film, what they do with a film's form (i.e., structure) will both limit and guide viewers' options. Form shapes the possible meanings that can be created from a film. Bordwell and Thompson (2004, 55–58) break film meanings down into four types: *referential, explicit, implicit,* and *symptomatic.* All films can be scrutinized by these four meanings, though many viewers never consciously consider them.

Referential meaning is a "bare-bones plot summary" that is "very concrete" (Bordwell & Thompson 2004, 55). For example, in the film *Snow White and the Seven Dwarfs* (Cottrell et al. 1937), an evil stepmother is upset that she is no longer the most beautiful woman in the kingdom. She orders her stepdaughter, Snow White, to be killed, but the person put in charge of doing this lets her escape. Snow White makes friends with some dwarves in the forest. The stepmother finds her and poisons her. She is revived when a prince kisses her. She and the prince fall in love and live happily ever after. This is a banal, generalized recitation of what the film shows us. It is merely referential.

Explicit meaning represents the core ideological point of the film. It is typically quite clearly presented in the film's form and points to the moral or global ideology being promoted. In the case of Snow White, it is something akin to "good triumphs over evil." The kindhearted are rewarded.

Implicit meanings are always myriad. Audiences create implicit meaning based on what they feel a film "suggests or implies." Thus, implicit meanings are always open to interpretation. In the case of Snow White, the implicit meanings range from cliché—"stepmothers are evil"—to socially complex and controversial (e.g., "ideal women are well-mannered housekeepers"). Other implicit meanings might include a scathing critique of narcissism and promotion of mirror-phobia.

Symptomatic meanings are the least likely to be created by general audiences but are very useful for film analysis and critique. Symptomatic meanings stemming from film form are those that are subsumed within a dominant ideology (i.e., mode of thought) at the time of production. Films are accidentally and purposefully embedded with contemporary beliefs, tensions, fears, or thoughts that dominate society at the time of their creation (e.g., patriarchy, capitalism, racism, political correctness, environmentalism, nationalism, right to privacy, etc.). Dominant ideologies are always manifest within films to some extent; however, films can also be used to promote counter-ideologies and critiques of society (Taylor 1999). For example, the film *South Park: Bigger, Longer & Uncut* (Parker 1999) is a complete take-down of United States prime modernity—American society's self-image. In Snow White, it might be surmised that patriarchy is one symptomatic meaning—women depend on strong men for survival: the huntsman, the dwarves, or the prince. This was a dominant discourse of the era, and the film effectively reified gender roles—by contrasting *Snow White's* discourse on gender roles to more contemporary animated films such as *Brave* and *Frozen*, the import of symptomatic meanings becomes hard to ignore. Also, the happy ending in Snow White is symptomatic of the fact that the United States was in the midst of an incredibly long depression when the film arrived in theaters; it represented hope for the future, even though it may have seemed as though all was lost.

THE LINK BETWEEN FILM AND MAP FORMS

All communication, and any subsequent meanings derived from it, depends on form. Though film (and to be fair, literature and graphic design) studies have theorized, conceptualized, and operationalized form so that it can be

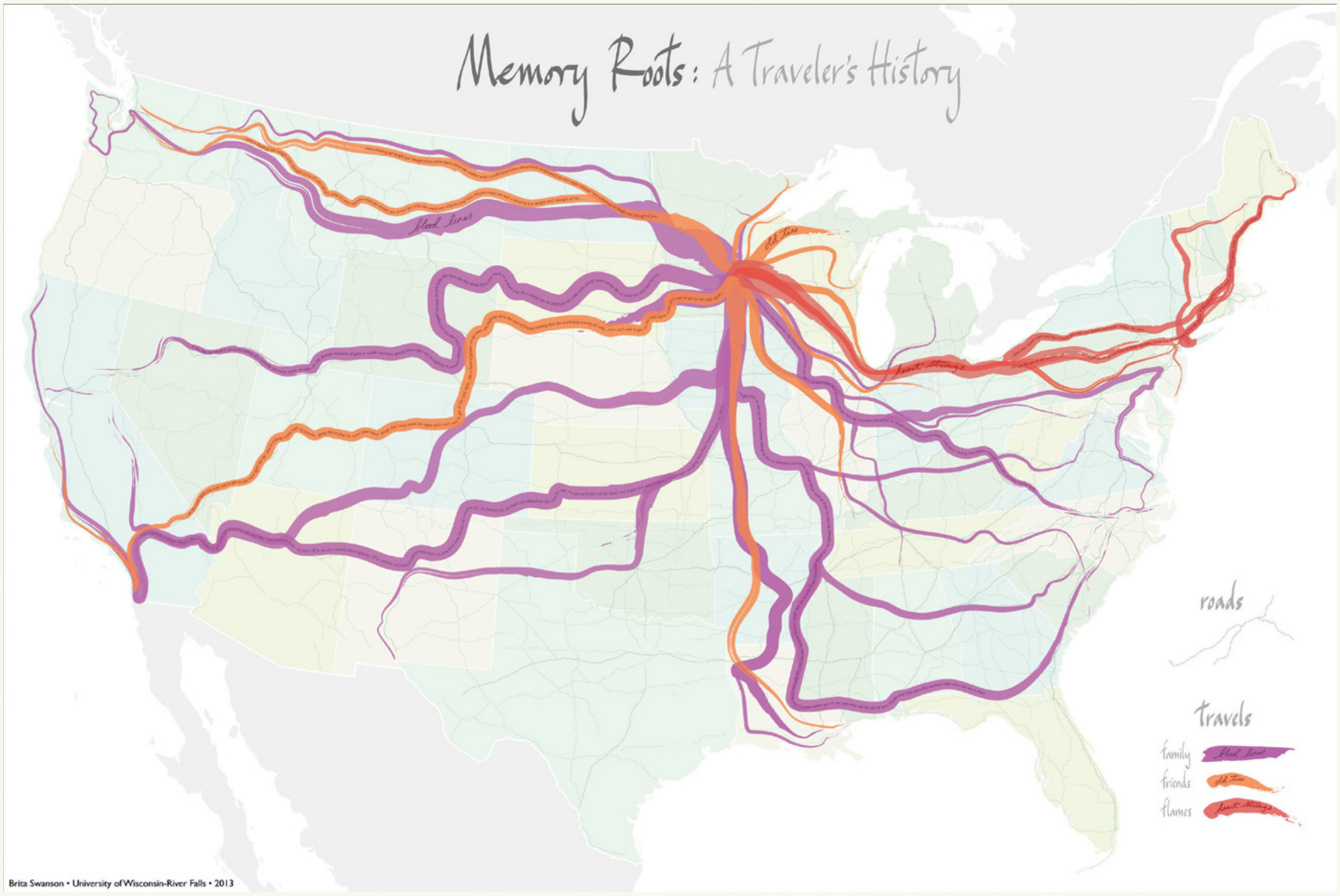

Figure 4: An example of a minimalist legend that reinforces motif and plays an important role in the entire form of the map (by Brita Swanson, University of Wisconsin–River Falls).

analyzed and critiqued, cartography has yet to come up with an easily applied strategy for doing so. The rest of this paper outlines how the above cinematic concepts might be parlayed into new approaches for analyzing and critiquing map design.

DEFINING MAP FORM

Like all forms, map form has a foundation. The foundation of map form is the medium on which it is presented. Just as a book's form is typically found between two bound covers, a paper map's form consists of everything encompassed on the sheet of paper. If instead one is using an interactive map on a tablet, then form is everything found on the screen. The meanings, ideologies, and eloquence of a map's communication will always be built upon its medium through the construction of form.

Map form is much more than just the content found within a frameline. Crucially, *form includes how objects found within the medium interact with and relate to all other objects found therein.* Cartographers have traditionally called many of these objects map elements and data (Dent, Torguson, & Hodler 2008). The key to understanding how a map helps users create meaning (e.g., understanding) is found in how well all map elements interact—their symbiosis. How accurately data are presented is frequently only one aspect of this. Evidence is beginning to accrue that emotional response to form is just as, if not more, important than the richness of data content when it comes to impactful visual design (Muehlenhaus 2012; Wrigley 2013). Map communication is always enhanced or hurt by decisions made about map form.

Unfortunately, cartography has a tendency to miss the big picture. Cartography textbooks often dwell on individual element design, with each element being treated and discussed in isolation, instead of focusing on map form broadly. For example, in a mapping class an instructor might spend considerable time teaching the appropriate design of a legend for quick and easy interpretation of a map. This is an example of map element fixation. When mapmakers are critiqued on the arrangement of elements inside a legend instead of how well the legend itself interacts with the other map elements, cartographers avoid discussing the main point of the map: how well it facilitates an interpreted meaning (Wood & Fels 1986). Yes, the legend has its own form, and there are conventions to be followed in most circumstances, but all of these rules should be broken if they do not support the effectiveness of the entire map's form. Just as films with good form will often tie scenes together via motifs, repetitive dialog, or color schemes, maps with good form will tie map elements together to facilitate the ideology or broader meanings a map is attempting to communicate (see Figure 4). Effective map form demands elements act in concert with one another.

Form includes everything, including the outcomes of data model decisions regarding what content to include in the mapped area and how to represent it. Many academic geographers still have indigestion over the ubiquitous use of the Web Mercator projection and the potential impact it will have on people's view of the world (Battersby, Finn, Usery, & Yamamoto 2014)—myself included—without admitting to themselves that any other projection is also an ideological decision and *just as unreal* as a Web Mercator. Deciding which projection to use as a cartographer is little different than filmmakers deciding which camera angle and lens-type to use when filming a scene: reality is constructed regardless of the lens chosen (Figure 5). Decisions made about how to present map elements and which elements to include are as central to map design as they are to a director deciding what to include in the background set of a studio shot. Like props on a set, a north arrow may

Figure 5: Top row: from the film Blood Simple *(Coen 1984), a camera view showing an office from the top down (i.e., the floor is visible but not the ceiling or walls), followed by a camera viewpoint from near the ground upward (i.e., the ceiling is visible but not the floor or walls). Both represent the office differently. Below, an example of two different projections used to show the Earth, both of which show the impossible: the entire world at once. Both of these scenes are fake: the office is a studio set; the Earth image is made-up and speculative of what the Earth would look like without humans.*

help your map communicate more clearly or look more scientific, but it may also distract from the meaning (i.e., interpretations) one is attempting to communicate. In some films, minimalism is the motif, whereas in others visual overstimulation is the goal. This is no different with maps; mapmaking involves making design decisions about what to include and exclude on a case-by-case basis, depending on your communicative goals.

MAP ELOQUENCE

Anyone who has used more than a handful of maps in their life knows that some maps are more eloquent in form than others. The emotional impact one receives viewing a map in the *Atlas of Design* (Wallace & Huffman 2012) or the *Atlas of World Affairs* (Smith 2012) is going to be much different than when looking at a map of the same information in a default GIS template. In cartography circles the eloquence of a map's form is often referred to—sans operationalized definition—as map style or aesthetics. In recent years there has been an alarmist concern among many cartographers—myself at times included—that map style and aesthetics are worsening. However, without a clear definition of what makes a map style better or worse, it has been very difficult to do much more than worry and opine about stylistic changes.

Applying Burke's (1968) concept of eloquence proves quite useful here. Rather than saying that map style and aesthetics are worsening with the ubiquity of GISs, or Web mapping APIs, it may be more accurate to say that a majority of these maps are exceedingly mannered in form and not always as effective as they might be. Contrarily, many of the maps created by those without a cartographic background and sans GISs may naturally end up having a more styled form. Many of these mapmakers' ideas of what a map is or should be are not guided by disciplinary conventions. An analogy might be made to watching a show produced for C-SPAN (or any other public news channel) versus one produced for MTV. C-SPAN information is very documentarian; MTV's is more visceral. However, if MTV-esque form were used in C-SPAN programming, it would cease

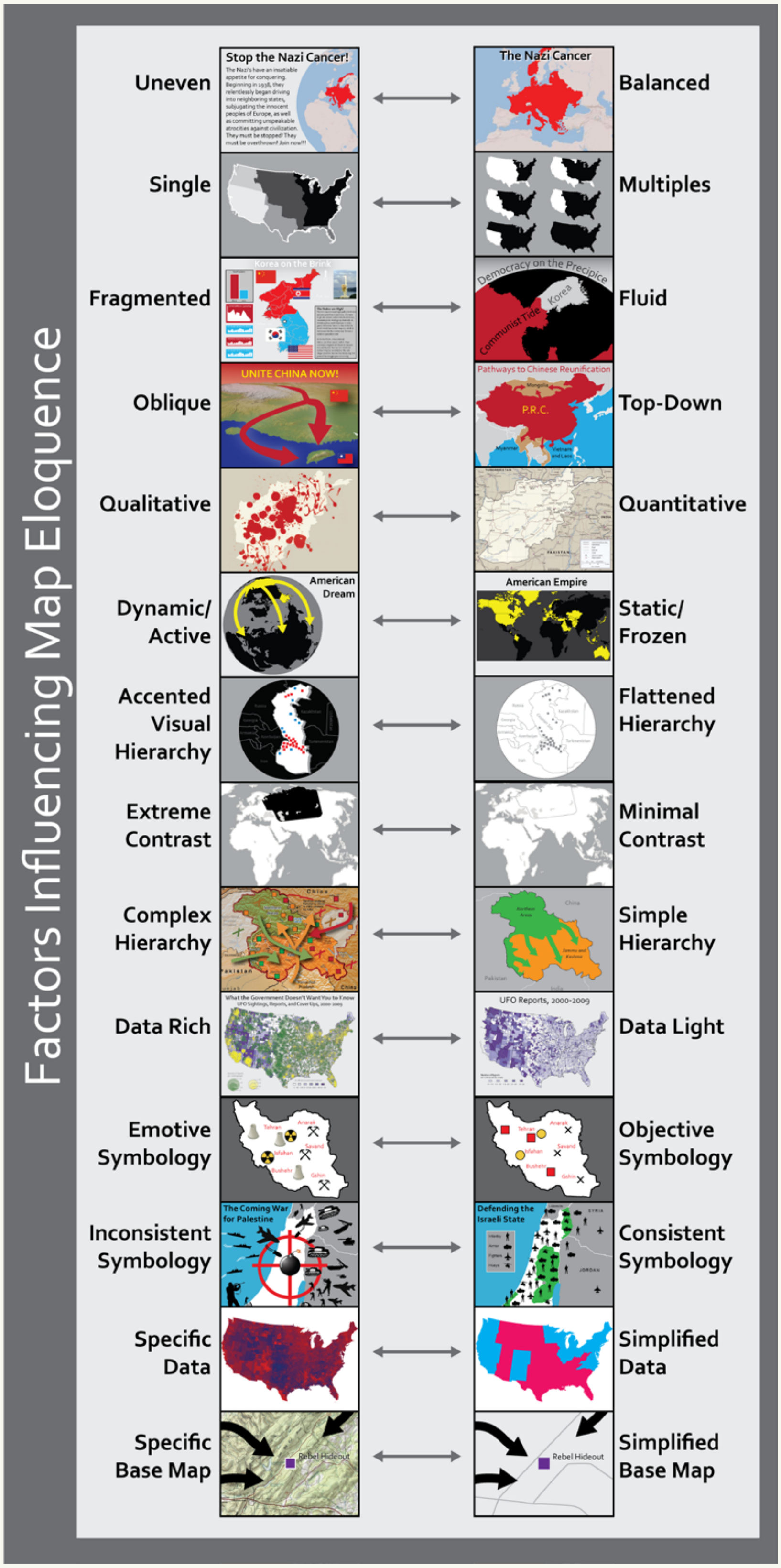

Figure 6: How my 2010 continuums based off of the work of Dondis (1973) might be arranged within Burke's (1968) model of eloquence. Further exploring and modifying these design concepts may allow cartographers to systematically address map form and determine which combinations of form manipulation produce more styled or mannered map aesthetics.

being C-SPAN to a majority of its viewers; they would likely rebel.

No maps are *purely* mannered or styled in form. All maps fall somewhere on an axis in between the two extremes. Those that fall in the middle are often the least eloquent in design; their form is confusing and ineffectual. The benefit of adopting Burke's (1968) mannered-versus-styled eloquence concept for use in studying map aesthetics is that it has already been accidentally expanded upon in graphic design and cartographic literature. Without stating as such, Dondis (1973) and Muehlenhaus (2011) have both proposed methods for analyzing different dimensions of form eloquence. Dondis (1973) proposes that all images, including film, can be analyzed based on different design decisions the designer makes. She breaks these down into numerous "continua" lying between two extremes—which she terms harmony and contrast (Dondis 1973, 110–125). In turn, I adapted many of Dondis' continua for use in map analysis (Muehlenhaus 2010; 2011). I was specifically interested in studying persuasive maps, but argued that the concepts were likely universal and applicable to all maps. Figure 6 highlights some of the continuums I proposed, placing them within Burke's (1968) mannered-versus-styled eloquence model. Theoretically, it may be possible to analyze maps based on these different continuums of map form, analyze the relationships between the continuums, and figure out which techniques coupled together result in more mannered or styled forms of eloquence. If we combine the hypotheses of Burke, Dondis, and myself, we should be able to, at least cursorily, analyze the eloquence of form in different maps.

EXAMPLE: EXPLORING THE ELOQUENCE OF A MINARD MAP

Charles Joseph Minard's maps from the 1800s are considered some of the greatest thematic cartographic works ever produced (Robinson 1982). His cartographic contributions are typically considered to be extraordinarily innovative when it comes to visualizing quantitative information (Tufte 1991). Thus, in this section one of his more famous flow maps (see Figure 7) has been chosen for exploratory analysis to better highlight the potential of analyzing map eloquence using ideas borrowed from film. In this map, Minard used the concept of proportional flow lines to highlight global migration in 1862. At first glance, one cannot help but opine that this map has certain panache and style that few maps from 1862 had. It is unique. Yet, this does not go very far in helping us understand why it still strikes people as a visual classic today.

Taking Burke's theory of eloquence and my own adaptation of Dondis for maps, we can quickly begin to break down map form into design decisions. The map is asymmetrical but balanced. It is a single map with a fragmented layout, top-down perspective, and quantitative representation. It is dynamic; it screams movement and interconnection. It has an accented visual hierarchy, punctuated by bright colors. The contrast is not unobvious but not excessively extreme. The visual hierarchy is quite simple for the amount of data being shown. By today's standards this map is fairly straightforward and might be considered data-light: it is not multivariate. The symbology is geometric and consistent. Though light on data, the representation of the data is extremely accurate. Numerous flow branches break off from the main immigration routes to show detail to relatively small places. Also, data numbers are provided throughout the map to help the map user interpret true values. The base map is intentionally generalized and simplified. The projection appears to be a legitimate cylindrical projection, but the landmasses are grossly distorted to fit the communication goals of the map (e.g., look at the size of Réunion Island in the Indian Ocean).

Though the above paragraph presents an admittedly unromantic cursory analysis of Minard's map, using a more specific approach to understanding map form might help cartographers better learn how to design timeless pieces of their own. Every map's form lies somewhere on the continuum between mannered and styled eloquence. I hypothesize here that it may be possible to standardize and analyze the eloquence of a map's form by further modifying or adapting my own (Muehlenhaus 2010; 2011) map design continuums. Though beyond the scope of this paper, it seems reasonable to suggest that mannered map forms probably tend to use opposite visual techniques than styled map forms. Regardless, the key takeaway from film studies is that cartographers can start exploring and critiquing map eloquence (i.e., aesthetics) more systematically and holistically than has been done previously. It will require, however, a leap of faith on the part of cartographers: a need to value map form over data accuracy and richness.

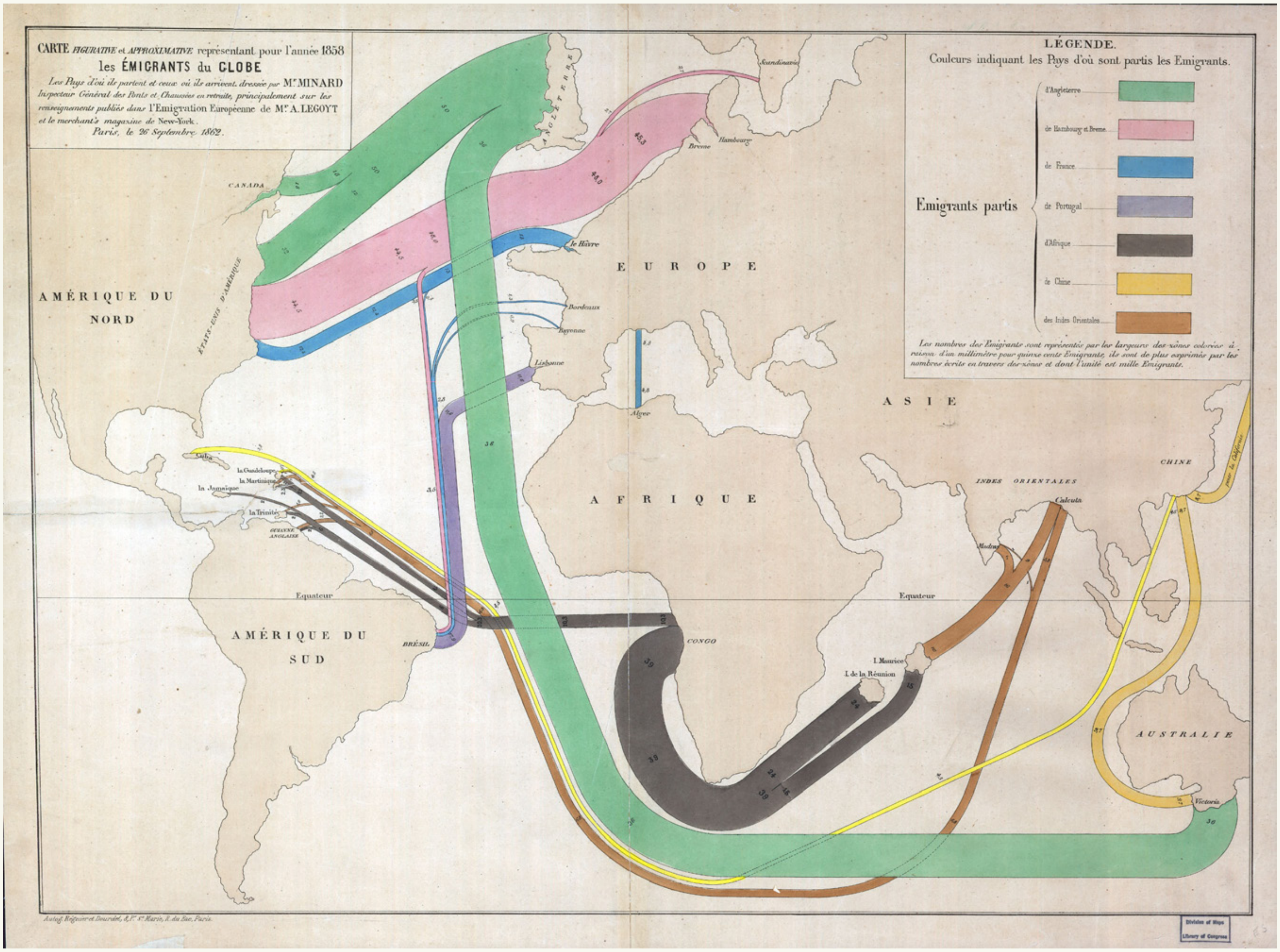

Figure 7: The Emigrants of the World *(title translated from French), by Charles Joseph Minard. 1862. Available online at cartographia.files.wordpress.com/2008/05/minard-full.jpg.*

MAP FORM, AUDIENCE EXPECTATIONS, AND MAP INTERPRETATION

As with film, map viewers bring expectations and thoughts about what maps are and should look like when they view them. In many situations, producing a map in a mannered style is ideal, because it makes use of visual cues that will allow map viewers to preemptively know what they should look for. Playing off of people's expectations is extremely useful, as it allows people to make decisions quickly and navigate a visual design. To use an earlier example, mystery dramas are not boring or bad by default, though a vast majority of these films follow exactly the same narrative structure. One reason mysteries are so widely watched is because familiarity of the film's form means that the audience can focus on its idiosyncratic aspects: subplots, characters, unique settings. In fact, Ovans (2014) has argued that narratives are so predictable they can be quantified and broken down into types. The same thing is possibly true for mannered maps.

For example, when viewing a *You-Are-Here* map in a mall, little is more frustrating than not being able to find where you are. One expects a large arrow. When such maps do not heed this convention, map users often become confused and angry. Searching for where you are on a map takes away from observing where one is in relation to other features on the map and also from the task of determining a route. When designing a *You-Are-Here* map, mannered form is ideal. People expect it. When designing maps for navigational uses, one should always consider map user expectations.

Figure 8: An example of a typographic map using form to pique an audience's appetite (by Martin Elmer, @maphugger, maphugger.com/post/38323044556/laconic-history-of-the-world-2012-my-first). The content itself might not garner much interest on its own had it been represented in mannered fashion. It is the styled eloquence that makes this map appealing and attention-grabbing.

On the other hand, many maps benefit from a styled form because it is their form that makes them worth viewing at all. If these maps were not styled, they may never have garnered one's attention to begin with. Examples of such form over function maps are those comprised entirely of typography (Figure 8). If one were simply to write the name of the most commonly used word found on each country's "History of…" Wikipedia page and label each country with it, few people would bother to look. However, the form and styled eloquence of the map—with its unexpected and flamboyant style and countries drawn using only type—draws people in. It makes the message exciting. It screams to be looked at; it wants the map user to create meaning from it. Contrary to what many academics espouse, people are very happy to choose form over function if the style is enticing. This has been known in cinema for a long time; people are happy to pay to see action movies with minimal plots and poor scripts over going to critically acclaimed dramas. Mannered form may earn critical accolades, but in most media, styled form earns income.

Like films, maps serve myriad purposes. Academic cartographers love to focus on information visualization and rightfully so. Arguably, maps can communicate far more spatial information, far more quickly, than any other method of communication invented. However, map form does not need to aspire to the rules of quantitatively accurate representation. In fact, many times it should not. Meaning is not created through the presentation of facts; meaning is created through the interpretation of form—which may or may not accurately represent facts (Burke 1968).

A map's form will impact how it is interpreted. It will cue readers as to the purpose of the map. As with film and writing (Chatman 1990), map form can be designed to do one of three things: (1) it can explain and describe (expository cartography); (2) it can narrate (narrative cartography); or (3) it can argue (persuasive cartography). These three objectives are not mutually exclusive; they often overlap. Narrative design can be used to help make an argument or explain something. Expository designs can be used to make ideological arguments or contextualize a narrative.

EXAMPLE: FORM, EXPECTATIONS, AND INTERPRETATION

Weapons for Destruction (Figure 9) was designed by Nathan Noble, an undergraduate student in my introductory cartography class. He created the map for a flow map lab assignment. As it was Nathan's first map and GIS course, he had not been indoctrinated with the idea that maps should strive to be objective. I was expecting the students to turn in a bunch of mannered, expository flow maps.

Weapons for Destruction is anything but a mannered, expository flow map. The unique projection places the United States at the top of the map, implying an overlord like power over the entire world. The flow arrows pierce out of the demonically colored United States like evil tentacles. The countries being penetrated by the arrows are colored white, implying the end of their innocence. Most tellingly, however, is the title. The title immediately informs the map user that this is not just another fake-objective map—it is a call to action! The map not only provides data, it provides an anti-US arms sales message, and acts in addition to this as a narrative map, providing a modern history of United States' arms sales to the world. Though some of the design decisions may not win any awards, the form of the map itself will garner attention by going against contemporary data map expectations, and people will likely interpret this map very differently than other representations of

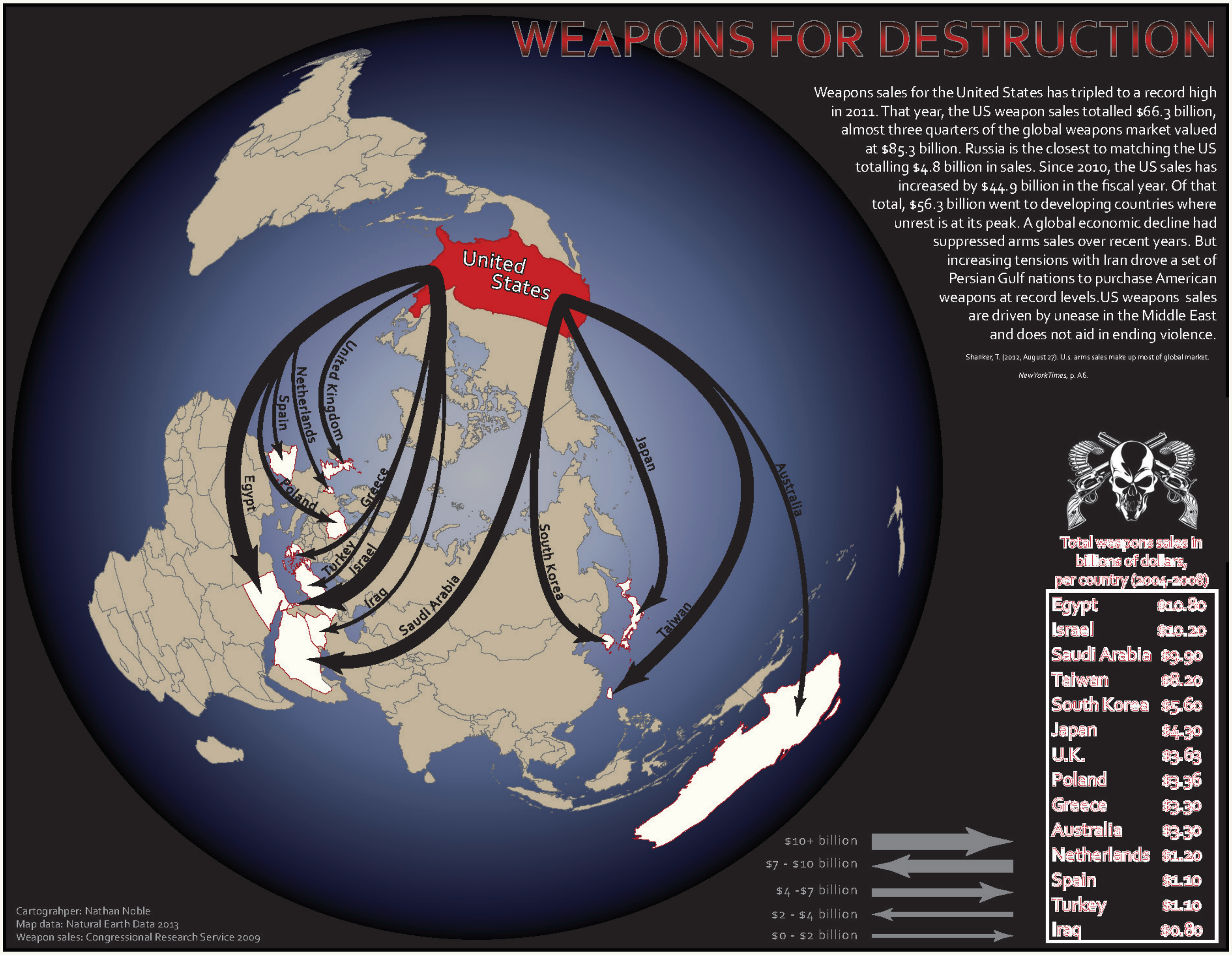

Figure 9: This map describes small arms shipments from the United States of America to the rest of the world (expository) and argues that the United States plays a negative role in the world because of its small arms sales (persuasive/argumentative). Map created by Nathan Noble, @THENateNoble, 2013, Department of Geography and Earth Science, University of Wisconsin–La Crosse.

arms sales due to the map's complex overlap of expository, argumentative, and narrative purpose.

As with film, map users are not passive interpreters. They engage the material and, depending on form, they will interpret the goals of a map differently. If the goal of one's map is to make an argument, to take a position on the way reality ought to be, then designing your map elements in such a way as to subjectively highlight one's biased position may be ideal. It will help map users immediately realize that the map is making an argument. Rather than turn map users off, overt subjectivity may actually make the argument being presented more convincing (Muehlenhaus 2012). Map form cues users about what to expect on a map and also about how to respond to it. The least meaningful maps are often those that do not adequately use form to promote a particular meaning.

MAP MEANINGS

> ***"To create is not to have an idea that searches for its form; to create is rather to have a form that searches for its meaning." — Gunnar Olsson (in Buttimer & Haegerstrand 1984, 01:01:30)***

Maps have never been about presenting data; they have always been about guiding an audience to create certain meanings—meanings that enlighten, persuade, or tell stories. Since Wood and Fels (1992), if not less explicitly before (Harley 1989), it has been known that something as banal as a state highway map is loaded with meanings beyond getting from point A to point B. As in film, the most objective-looking maps make effective use of form to help map users "suspend their disbelief" (i.e., they stop being aware of the fact that what is being viewed is a completely fabricated version of reality). The power of maps is never truly found in their referential meanings; the power of maps is found in their explicit, implicit, and symptomatic meanings.

Determining a map's multiple meanings is a creative process. It begins with the cartographer, who uses map form to limit and guide map users' interpretations. It then moves on to the map user who, given a variety of visual cues, must create meaning from the map using a combination of previous map-reading experience, expectations, cultural norms, and personal biases. Here the four types of meaning espoused in film studies again prove useful when adapted to maps. For even though a map user may think they are only creating a referential meaning when looking at a map (e.g., number of whales harpooned off of Norway each year), and perhaps an explicit meaning (e.g., whale hunting is bad), subconsciously they are creating or at least reifying other implicit meanings (i.e., Norway is bad because it allows whale hunting). Figure 10 represents a map with myriad meanings (Windsor & Muehlenhaus 2013). From an information visualization standpoint, this map may generalize too much and may not satisfactorily attempt to be objective. However, evaluated on the basis of map form, the map is layered with meaning.

Symptomatic meanings are often completely left unattended by a map user, but they are also there to be interpreted and created in every map. What is the rationale or reason for the existence of a map about Norwegian whale hunting? This question is generally too philosophical or abstract for general audiences to focus on, but it is a question that those in the geographical sciences should be as interested in as any other. What is any given map's role in society at large? Why did it come out when it did, and why was it distributed to a certain population? Why was its reception so positive, negative, or neutral? These are the questions used to understand a map's symptomatic meaning. Certainly such research contextualizing mapmaking is ongoing (see for example work by Jeremy Crampton [1995] and Pickles [2004]), but often critical cartography is treated separately from cartographic design. It should not be; interpreting the symptomatic meanings of maps is as fundamental to understanding how maps work as knowing about appropriate quantitative representation.

EXAMPLE: IDENTIFYING THE MEANINGS OF BIG DATA MAPS

Every map has meaning; in some maps, however, meaning is more difficult to find than in others. Big data maps often suffer from this problem. It can be difficult to consciously create explicit or implicit meanings from big data maps, as the maps are often data-centric and the information being presented is non sequitur. For example, what are the implicit and explicit meanings of a map animating one million live tweets about the Super Bowl (see **srogers.cartodb.com/viz/1b9b0670-8d15-11e3-8ddf-0edd25b1ac90/embed_map**)? The big data maps that will truly stand out are those that adequately posit explicit and implicit meaning. Generally, this will require presenting

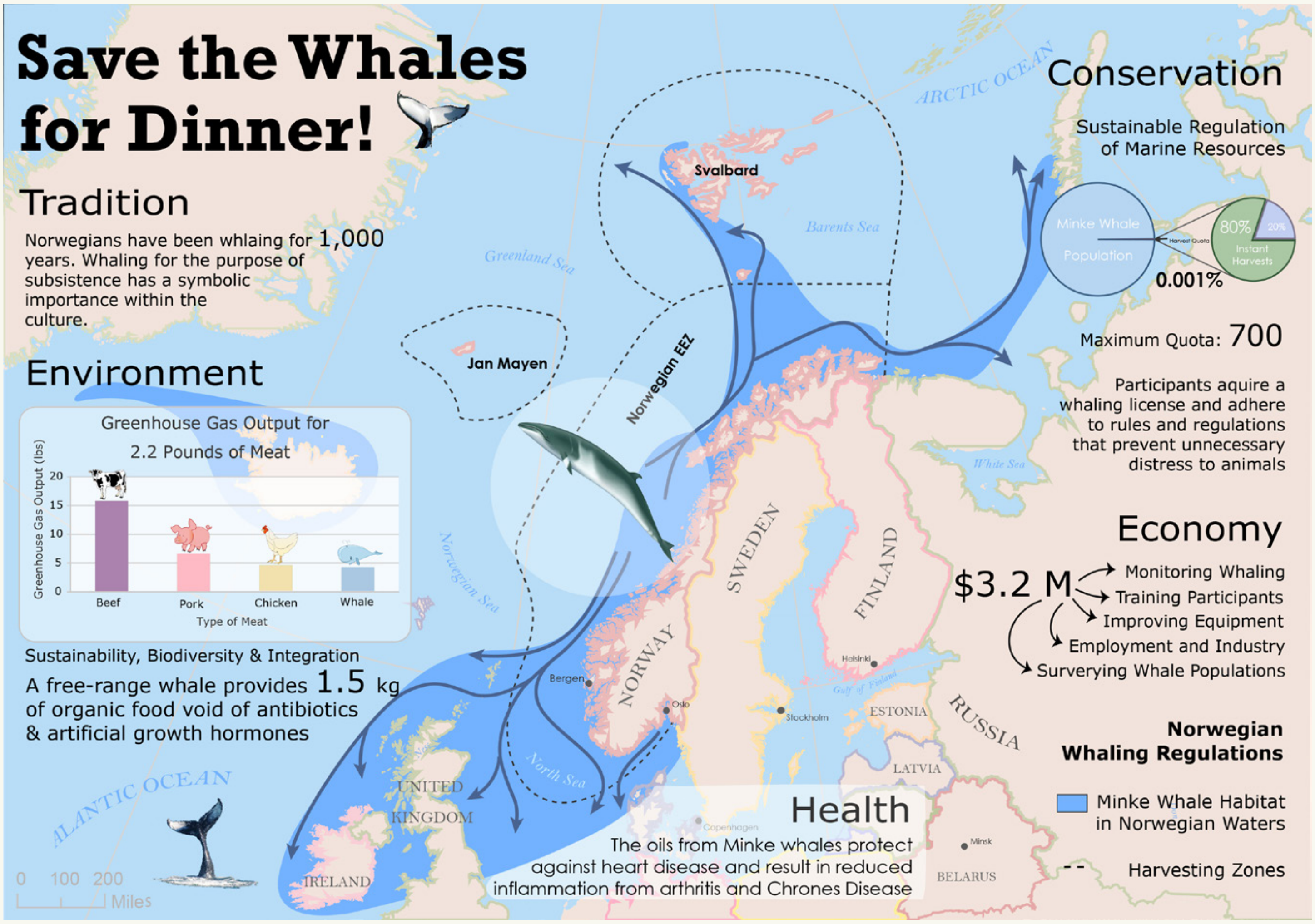

Figure 10: This map was created for a project testing the impact of persuasive map design (Windsor and Muehlenhaus 2013). The map is pro-Norwegian whale hunting. The goal was to create a map that made map viewers explicitly, and preferably implicitly, decide that Norway's whale hunting was probably ethical and not bad for the environment. Map created by Mary Windsor, University of South Carolina, who, for the record, does not condone whale hunting.

a description, narrative, or argument of intrinsic value to those viewing the map—e.g., climate change, human trafficking, etc. Though a cool looking animation, Super Bowl tweets probably will not make the cut.

This is not to say that the thousands of big data maps being produced these days have no value or meaning. In fact, they are fascinating in what they tell us about society at large. Big data maps might best be described as manifestations of society's obsession with the massive amounts of social data being collected and shared right now. These maps represent creative outlets stemming from contemporary society's data-fetishism. Though the data being mapped may not highlight anything of interest, the maps themselves still have meaning. They are symptomatic of, and reinforce what might best be called the "Positivism 2.0" ideology that dominates in the sciences right now.

RETHINKING MAP EVALUATION AND CRITIQUE

Map evaluation and critique are key components of the cartographic discipline. It is through critique that mapmakers hone their skills. It is through emulation of exemplars that standards are set and conventions become assigned. All disciplines have their own rules for evaluating what is conventional and unconventional. Such rules are not only used to forge discipline standards, but to maintain the socially constructed discipline itself. Though mapmaking has been around forever, cartography as a discipline has not (McMaster & McMaster 2002; Wood 2003). During this time, the cartographic discipline has had a limited, indeed quite academically conservative, view of how maps should look (Muehlenhaus 2013). In the discipline, maps are often evaluated based on content instead of form.

Accuracy is often at the forefront of critique in cartography. However, film studies illustrate the power of critiquing media based on form. It is proposed here that critiquing maps not on discipline conventions but instead on their form may result in more useful and meaningful evaluations. Adopting film studies-like critiques in cartography, we can start evaluating maps based on how layered and nuanced their meanings are, and how eloquently they achieve their purpose, instead of basing our evaluations on a hodge-podge of traits such as how accurate, scientific, and modern they are. Instead of grading maps based on depth of data, we can analyze them on the depth of their expositions, narratives, and arguments—how convincingly they make us suspend our disbelief and open new paths of understanding.

Additionally, analyzing contemporary maps' symptomatic meanings will indubitably shed far more light on how unique or creative a map design truly is. Joseph Minard's maps were symptomatic of the rise of the nation-state and showed the potential power of thematically representing newly acquired economic and demographic data (Robinson 1982). He experimented with flow maps that today the best GIS programs still cannot mimic. The reason his maps are remembered, though, is not for their quantitative depth or flow lines: it is because of their form. They are stunningly eloquent. Likewise, in 10 years all of the Beck-themed maps of highway and anatomy systems—many of which are indeed quite beautiful—will likely be more accurately seen for what they really are: a symptom of a Reddit MapPorn addiction, while Beck's original map will remain a classic (for a critique of the contemporary abundance of Beck-themed maps, see Cartwright & Field [2013]).

FUTURE DIRECTIONS

Adapting cinema's concept of form for cartography is not necessarily an end in itself; it potentially opens up numerous avenues for map analysis and classification. Though form and meanings are unique for each map and individual map user, it is likely that certain genres exist and are identifiable. Genre is central to film analysis, but its definition is a bit looser than that of film form. The word comes from French and means "kind" or "type." It is a way of grouping films together based on their form, meanings, and other attributes (Schatz 1981). A map genre therefore might be defined as clusters of map types determined by map form, purpose, and meaning.

An argument could be made that map genres are already defined. After all, cartographers talk about thematic, reference, and perceptual maps. Within thematic cartography we have a variety of sub-categories (e.g., choropleth, isarithmic, and dot maps). We also have Web maps, persuasive maps, and story maps. Theoretically, all of these might be thought of as genres. However, if cartographers start focusing on map form, a more robust and aesthetics-centric group of genres may present themselves. New genres and subgenres that were never obvious may emerge as well. Most interestingly, establishing map genres based on form may help us better identify what makes certain maps "classic." It may also shed light on major shifts in map aesthetic and eloquence, as certain maps might be identified as genre-busters (i.e., some may break the mold of a genre to create new sub-genres or redefine what a genre is). For example, Beck's underground map would almost certainly qualify as a genre buster when it comes to reference maps. More recently, the definition of a reference map was shattered by Google Maps' multimedia, multiscaled, slippy map approach.

Another area of film studies to look at adapting may be in the area of discourse-texts. Chatman (1990) argues that films and literature take one of three broad discourse structures: descriptive (i.e., expository), narrative (i.e., story), or persuasive (i.e., argumentative). More systematically addressing how map discourse is constructed based on film and literature theory may be help us better understand map types that are not merely expository. This would be of particular benefit given the contemporary resurgent interest in narrative cartography fueled in part by Esri Story Maps. Stories can be told in a multitude of ways, and exploration of how to implement different plot-development and argumentative devices into maps is an area definitely ripe for exploration.

CONCLUSION

Cartography and film have a synergetic relationship. Just as filmmakers are increasingly turning to cartographic theory to learn more about their art form, cartographers stand to gain by adapting relevant film concepts. I have argued here that applying film theory's concept of form to maps will help us better define and understand map aesthetics, purpose, and meaning.

Embracing the concepts of form, eloquence, and meaning is imperative for designing effective maps. The manipulation of form is what guides and fosters meanings among map users. The concept of eloquence may be a foundational cornerstone that finally allows cartographers to better address map aesthetic. Furthermore, evaluation of map form and meaning—instead of particular map objects and or data content—may provide cartographers a more sophisticated and nuanced method of map critique.

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Map Portraits

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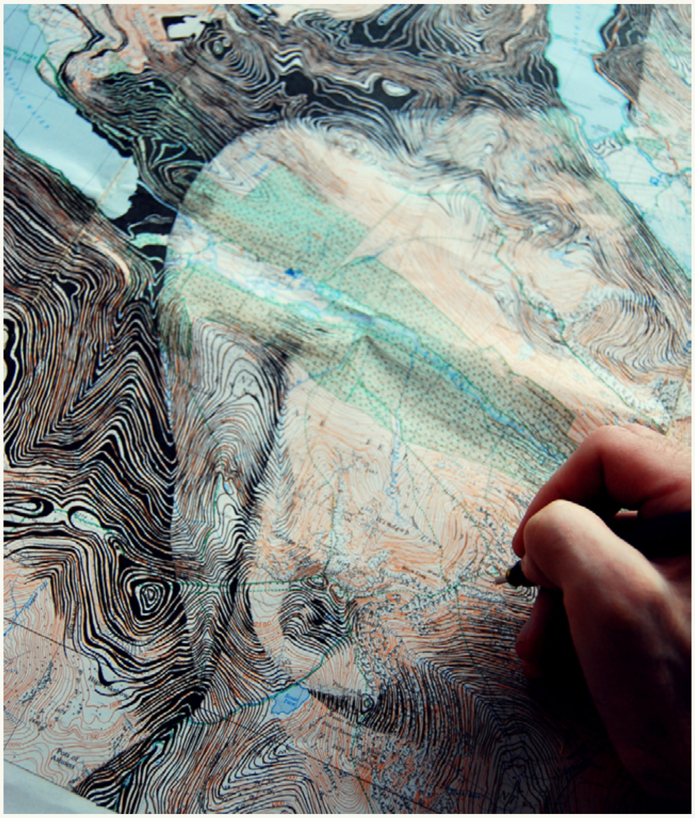
People often ask me if I see faces in maps. Sometimes people assume I do. I can appreciate the art of seeing faces in things (pareidolia… and yes, I did have to look it up), like observing familiar shapes and objects in the clouds, but it's not something I actually do.

When I begin working with a map, or a set of maps (my studio is full of them), I study the rough shapes, the potential compositions and sweeping directions, making a mental note of any obvious or sharp characteristics. This is a framework, and a very loose one. As an artist, I can demolish or invent terrain, but mostly I hijack it, highlighting chosen parts of it. My framework is a "best fit" for the figure and the land that holds her; the lengthy process from here involves manipulating the organic patterns on the map to show both the landscape and the human form.

The parts I pick to draw over and around the landscape are, in relation to one another, the same ingredients laid upon the same composition as a portrait on white paper. It's just that I find white paper uninteresting. So instead I utilize patterns, literally drawing upon the similarities that exist between us and those patterns—in the case of the majority of my work, what I find really interesting, those patterns are maps.

I feel fortunate to work with an ever-changing surface. The landscape is organic and unpredictable, like a fingerprint (very appropriate). Immersing myself in cartography means that I'm always exploring, even if this exploration is on a limited level from the comfort of my studio. I do of course love to travel when I'm not working, and I get curious about particular parts of various maps when I am working—I often find myself researching places, for no obvious reason. I think I'm reminding myself that many other places do actually exist, on a very real level—"many" being the key word. A small town is just a word on a map, but away from the map that town has occupants, a history, accomplishments and everything else your own hometown has.



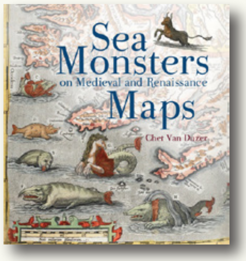
I think it's both the satisfaction of synchronizing the human form with our landscapes and the excitement of actually revealing those landscapes through a pencil that makes this project an ongoing one. Sometimes I wonder how many miles, to the respective scale of each map, my pens and pencils have travelled. Each sweeping stroke is far enough.

Being able to see the landscapes first-hand is always a delight. I feel I now have a greater understanding of (or familiarity with) the geography around me. I know what to expect in certain places: the shapes of the mountains, how the flow of rivers relate to the surrounding hills. By extension I know roughly which maps will show what, but just like a "real" explorer, I'm always keen to discover new places.

Ed Fairburn graduated from CSAD (Cardiff School of Art and Design) in 2012. He is represented in the US by the Mike Wright Gallery and also exhibiting work in various UK galleries and a selection of international venues. More information about Ed and his work is available at ***edfairburn.com****.*

Visual Fields focuses on the appreciation of cartographic aesthetics and design, featuring examples of inspirational, beautiful, and intriguing work. Suggestions of works that will help enhance the appreciation and understanding of the cartographic arts are welcomed, and should be directed to the section editor, Laura McCormick: laura@xnrproductions.com.

SEA MONSTERS ON MEDIEVAL AND RENAISSANCE MAPS



By Chet Van Duzer.

British Library, 2013. Distributed by University of Chicago Press.

144 pages, 115 color plates. $35, cloth bound.

ISBN: 978-0-712-35890-3

Review by: Mark Denil

Figures of creatures on maps are, these days, a thoroughly suspect phenomenon. The prevailing paradigm for "serious" cartography discounts maps sporting such illustrations: they are commonly accounted as comical, or touristy; as kitschy, or as suitable for juveniles. Certainly, a map displaying anything like a monster on its face, cartouche, or surround is instantly identified as either depicting a fantasy landscape or as attempting to appear antique, or both. Because of this, the use of monsters on maps is extremely difficult to pull off in this day and age without looking cheap-jack and phoney.

Nevertheless, in Medieval and Renaissance times the use of monsters (along with kings, banners, flora, et cetera) on maps was an integral part of the cartographic vocabulary. Including a monster (or a king, a banner, or whatnot) denoted and connoted broadly understood statements about things like the environs of that place, general dangers in the world, or the affluence of the purchaser. So, obviously, while a sea monster on a map means one set of things to us today, it would have meant a rather different set of things to someone in Medieval or Renaissance times.

There are a number of scholarly and popular works which mention the use of monsters on maps, but very few that deal exclusively and comprehensively with sea monsters. The new book published by the British Library, *Sea Monsters on Medieval and Renaissance Maps*, is significant, therefore, both in regard to topic and to quality.

The fabulous and the grotesque have a strong hold on the imagination of humanity, regardless of intellectual constructs such as rationalism, and stake their territory on the fringes of the known, well away from the banality of the familiar. The locus of that fringe has, of course, wandered hither and yon over the years: Egypt, China, Congo, Virginia, or the Deep Blue Sea, but the catalog of wonders supposed to be found there coalesced, despite the creatures' occasional forced house-move, into a solid and enduring heritage that has come down to us through the works of traditional authorities. Works by the ancient Greek Ctesias, the Roman Pliny, and the Medieval Europeans Polo, Mandeville, and Nikitin all cataloged the monstrous and marvelous things to be seen in the world, often jumbling what we would consider incomplete reporting with fantastical lies. For the Classical, Medieval, and Renaissance reader, however, the canon of the monstrous, grotesque, and fabulous was a solid and respectable body of work. The obsessive division of written and graphic works into rigid categories of literary vs. non-literary, or imaginative vs. factual, is a modern one, and regardless of how we might view them today, these works were the foundation upon which our current, self-styled scientific, knowledge of the world was erected.

Then as now, in mapping the world, it is natural that cartographers look to include what information is at hand. Data, then as now, are taken from both old-standby, go-to sources and emerging accounts of new discoveries, and on occasion hindsight may show the choice of one or the other to have been less than ideal. In Medieval and Renaissance times, what we see now as the literature of wonders was an integral part of what was known; especially of what was known about places little known. "Like the giraffe and the duckbilled platypus, the creatures of these remoter regions … are exceedingly improbable. Nevertheless they exist, they are facts of observation; and, as such, they cannot be ignored by anyone honestly trying to understand the world in which he lives" (Huxley 1956, 84). Or, in the words of Walter Shandy: "Would I had seen a white bear (for how can I imagine it?)" (Sterne [1759–67] 1980, 285).

What qualifies something as a monster, and, specifically, what constituted a monster to the Medieval or Renaissance mind? Are monsters abominations against nature (as Mandeville and others wrote), or are they adornments of God's universe, as Isidore and St. Augustine thought? Clearly they could be both or either, and a lot of what we see as sea *creatures* (whales, walruses, or manatees, for example) were considered sea *monsters* in the Middle Ages and Renaissance. For the purposes of this book, the author Van Duzer defines a sea monster as an aquatic creature that was thought astonishing and exotic in Classical, Medieval, or Renaissance times, regardless of whether it was in fact real or mythical.

Mapmakers back then, as has been noted, drew information for their maps from a range of sources; some standard, reliable fallbacks and others new and cutting edge. Their sources for sea monsters were also similarly varied, and Van Duzer explores this pedigree. He painstakingly tracks down antecedents for individual sea monsters in literature, illustrations, and other maps, and traces their descendants through maps drawn later. He makes it clear that sea monsters are normally creatures with lineage, and not just sports of the individual map maker or map illuminator.

This makes sense when we also learn that the inclusion of sea monsters on hand drawn maps was far from common. Evidence points to their presence as more often an indication of the conspicuous affluence of the client than as a locator for specific significant dangers to vessels or seafarers. Someone ordering a map with sea monsters would want recognizable monsters, charismatic monsters with a story to tell, monsters one could look up in whatever they used in those days for Wikipedia. In the age before map printing, when each copy of any map would be either specifically commissioned or deliberately composed on speculation, figurations such as sea monsters were costly additions. In some cases it seems clear that additional artists were brought onto the project to add sea monsters after the geographic elements and other map furniture had been completed, and surviving business records show price differentials for maps with and without monsters. Nowadays, of course, optional extras are usually restricted to more mundane things like lamination.

An informal and non-exhaustive survey which I conducted indicates that monsters do not feature particularly frequently on newer maps. Certainly, most monsters, such as dog-headed men, gryphons, or cyclopes, have generally fared rather badly in the modern imagination, but sea monsters seem to be remembered somewhat more kindly. In the 1920s, Somerset Maugham wrote that "When I set out in the morning the dew was so heavy that I could see it falling, and the sky was grey; but in a little while the sun pierced through and in the sky, blue now, the cumulus clouds were like the white sea-monsters gamboling sedately round the North Pole" (Maugham [1930] 1967, 48). This fond persistence is perhaps due both to the continued status of the abysmal sea as mysterious and remote (yet uncomfortably near at hand), and to the extraordinary insouciance with which the old sea monsters disport and splash about, even while devouring distressed seamen.

Chet Van Duzer's *Sea Monsters on Medieval and Renaissance Maps* is a slim volume bound in blue cloth with gold foil lettering on the spine. It sports a glossy dust jacket with full bleed, enlarged details of hand-colored maps from the *Theatrum Orbis Terrarum* of Ortelius, showing monsters in the seas off Iceland (on the front) and the Holy Land (on the back). Just inside, the front and back endpapers also boast excellent monochrome enlargements of sea monsters taken from engraved maps by, respectively, Sophianos and Mercator.

The publisher lists the book's dimensions as 8 × 9 inches, but my copy seems to have grown slightly; my tape measure gives pages of 8½ × 9½ (cover 9 × 9¾). In any event, the pages are nice and broad, with lots of space for two columns of text and fine, uncrowded pictures.

The illustrations are clearly one of the great strengths of this book. The jacket illustrations, already mentioned, are from examples housed in the British Library, as are many, but far from all, of the 115 fine reproductions on the inside pages. The paper used is bright, opaque, and smooth without being too glossy, and is well suited to receiving the images.

The text is divided into thirty-nine chapters, supported by opening matter plus ending notes and indexes, and interspersed with four thematic *Pictorial Excursus* (or, if you prefer, *excursuses*, although that term strikes me as a tad gauche). These are double page spreads, each with eight 3 × 3½ inch map details and captions. Three of the four excursus deal generally with sea monsters ("The Dangers of…," "Whimsical…," and "More Whimsical…"), while the other depicts episodes from "The Cartographic Career of the Walrus." The chapters address various aspects of the sea monster phenomenon, progressing more or less chronologically from their earliest medieval appearances in tenth-century *mappamundi* to their late, anachronistic, employment in the late sixteenth century.

I have mentioned the excellent illustrations from varied sources, but, oddly, there is no comprehensive list of source maps. The supplied list of *manuscripts* cites sixty-four separate documents residing in thirty-seven different collections (eleven of the 64 from the British Library, seven from the Bibliothèque nationale de France, and the rest from elsewhere), but the book also has a number of illustrations from *printed* maps, and these are not listed. Source information for printed examples must be gleaned from the text and captions.

Only one illustration is obviously badly cropped: the map of the harbor of Brindisi with sea monsters in a late eleventh-century manuscript of Lucan's *Pharsalia* (Figure 12, on page 25). The text describes various figures on either side of a tongue of land, but the upper figures are almost completely beyond the top edge of the picture.

All in all, I find this book to be an excellent discussion and sampler on the topic of sea monsters on maps. It covers, in a broadly accessible manner, the whole of the period of their common use, and establishes a pedigree for the practice of their inclusion. It proposes and discusses the medieval roots of the sea monster as a feature of cartographic furniture, the traditional vocabulary (rooted in classical pictorial practice and in contemporary evolving knowledge), and the grammar for their inclusion on the map face. It shows the birth, flowering, zenith, and decay of the practice, using well-chosen examples from a wide variety of sources, illustrated at appropriate scales with clear, sharp reproductions. Reasonably priced at $35, it gathers together examples of sea monsters from maps that it would be onerous for an individual to wander about to see personally (even for someone living only eight blocks from the Library of Congress, where more than a few of the originals reside).

Van Duzer writes in his introduction: "To medieval and Renaissance beholders, the sea monsters on European maps represented real dangers, but to modern eyes they are among the more engaging elements of old maps, whether swimming vigorously, gamboling amid the waves, attacking ships, or simply displaying themselves for our appreciation" (8). Without a doubt, the sea monster is seen today as an iconic, albeit quaint and curious, element of old maps and charts depicting the sea; iconic, that is, regardless of how atypical it may have been even in its heyday.

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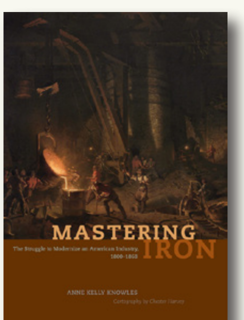
MASTERING IRON: THE STRUGGLE TO MODERNIZE AN AMERICAN INDUSTRY, 1800–1868



By Anne Kelly Knowles.

University of Chicago Press, 2013.

336 pages, 66 color plates and 10 halftones (approximately half are maps), 2 line drawings, 8 tables. $45.00, hardcover.

ISBN: 978-0-226-44859-6

Review by: Joseph Stoll, Syracuse University

It was with great anticipation that I opened *Mastering Iron*, having previously heard highly positive comments and having seen glowing reviews. I found that the contents of the book fully justified what I had heard and seen. This is a most handsome book, and exudes high quality throughout. The cover is nicely designed and encloses pages of durable weight and finish. The pages are richly illustrated and includes colorful maps along with evocative period artwork.

In the introductory chapter, "Iron in America," Knowles explains the rise of iron's importance in the late 18th and 19th centuries, and its role in fueling the Industrial Revolution. The author further discusses how historical and economic studies have failed to compare development of iron industries across the iron regions of the US. These studies also lacked a comprehensive approach to factors of development. The scope of Knowles' study is described as one that reconstructs and understands the concrete places and regions where iron was made, including the variety of factors that came into play throughout those places—labor, management, transportation, modes of production, and immigration.

In Chapter 1, "Mapping the Iron Industry," Knowles begins with a mid-19th century cycle of events. This cycle included the importation of cheap iron from Britain that was countered with increased US tariffs to stimulate domestic iron production. This in turn caused overcapacity, again inviting cheap British imports that further depressed the American market. In the mid-1850s, ironworks began closing as the economy spiraled into the Panic of 1857.

At the beginning of this crisis, the American Iron Association (AIA) was formed by East Coast iron manufacturers. The AIA's constitution was written by J. Peter Lesley, its first secretary, who was also a topographical geologist. Lesley, along with Benjamin Lyman and Joseph Lesley, attempted to survey the entire iron industry from Maine to Alabama in order to comprehend its state. This effort resulted in *The Iron Manufacturer's Guide*—a giant reference work. *The Iron Manufacturer's Guide* became the basis of Anne Kelly Knowles' work. She extracted data from each textual entry and parsed the details into a relational data base, connected them to geographical locations in a locational database and linked them into a "Lesley Historical Geographical Information System."

Knowles uses the contents of Lesley's survey to answer basic questions about the historical geography of the American iron industry. These questions address a range of topics: how the industry spread and changed, regional rates of growth and decline, extent and rate of adoption of the British model, regional developmental differences, etc. Knowles uses GIS-generated maps and diagrams along with tables to frame the discussion of these questions. The author also discusses the surveyors' difficulties and attitudes that come to light in their correspondence and notes, and how these might have influenced the data they collected.

In Chapter 2, "The Worlds of Ironworkers," Knowles begins by using art and literature to identify the living conditions of iron workers, and the environmental hazards and health risks they encountered. She discusses the distinctions in the rural areas, villages, and cities in which Lesley found ironworks, but notes that Lesley's distinctions did not fully represent the character of places where iron was made. Her discussion looks at a broader variety of ironmaking communities, and the social and economic relationships found in them. This discussion identifies regional differences in ironmaking and general characteristics of work environments and labor relations.

In Chapter 3, "High Hopes and Failure," Knowles recounts the American attempts to adopt the British model of developing coal-fired ironworks, undertaken to sustain the mass-production of iron necessary to supply the needs of US industry, agriculture, and railroads. Knowles describes the Welsh Dowlais Ironworks, and the efforts to replicate this Welsh model at the Lycoming Company in Farrandsville, PA and the Lonaconing Company in Lonaconing, MD. She analyzes the problems and failures encountered at these places, providing an explanation of the slowness of modernization of the mid-19th century US iron industry.

In Chapter 4, "The Elements of Success," Knowles turns to more successful examples of adoption of the British model of iron-making. These examples include the Lehigh Crane Iron Works in Catasauqua, PA and the Trenton Iron Works in Trenton, NJ.

In Chapter 5, "Iron for the Civil War," Knowles discusses the industrial production capacity with which each side entered the war. She also discusses the ways each side was affected by the industrial demands of wartime, as well as the war's effects on recruitment and retention of skilled iron laborers. The discussion also includes social and economic aspects related to wartime production, labor, and management. The description of iron production in the South features the Shelby Iron Company in central Alabama, whereas the discussion of Northern iron production includes the Union's industrial advantages over the South and the myriad technologies they used. For both sides, product quality proved to be of vital concern.

In the concluding chapter, "American Iron," Knowles summarizes the state of US iron manufacturing following the Civil War. This summary looks at regions, stories, individuals, and technologies involved in the changes that occurred between the antebellum and postbellum periods of iron manufacturing. The US industry is also compared to the British and European models of manufacturing, with explanations of the distinctions that developed in the US—including not just technology, but also labor-management relations.

At the end of the book, Knowles includes over 70 pages of useful material, beginning with "A Note on Historical GIS" that contains the sources used for the Lesley Historical Geographic Information System. Also included in this segment are notes, a glossary, and a bibliography.

There are multiple ways to approach this book. In addition to simply reading it in the conventional fashion, a reader can meaningfully navigate via graphics. With so many rich maps and illustrations that are stories in and of themselves, one can move sequentially through these and search out the textual content that is relevant to each. In fact, I repeatedly approached the book in exactly this manner. Still another method is to seek out the main characters and case studies in the book, to appreciate the in-depth scholarship the author demonstrates and the scope of the material covered.

The content of this book will be of interest to those in a variety of academic disciplines. To me, it seems particularly well-suited to historians and geographers—especially those with cultural, economic, and industrial interests. In addition, anthropologists, sociologists, and even art and literature historians will find the scope of material to be of interest.

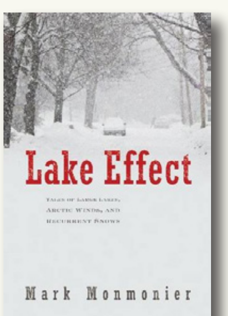
There is so much to admire in *Mastering Iron* that any criticism is certain to seem petty. If a subsequent edition of this book is written, I would offer a pair of suggestions based entirely on my own approach and experience. First, I would welcome an introductory section to serve as a "layperson's guide to iron-making." The glossary, which appears at the end of the book, is helpful; however, an early survey of the technology and key developments in iron-making (perhaps including a timeline) would be of great benefit. There is an immensely helpful section in Chapter 5 that explains the puddling, boiling, and Bessemer processes in production. Many readers would likely appreciate having these and other related processes explained at the beginning of the book, to increase their understanding throughout.

A second suggestion relates to the maps and is as much an observation as a suggestion. There appears to be a variety of symbol design schemes among the different maps. For example, Figure 63 is a map showing Confederate ironworks and Union territorial gains, 1861–65. This map uses symbols of distinct shapes and hues to distinguish different types of ironworks. Figure 14 is a map showing furnaces and deposits of iron ore and coal, using only hue to distinguish between different types of furnaces. Figure 17 shows sources of semifinished iron and iron ore for rolling mills, ca. 1854–58. This map uses yet another combination, with sizes and hues to distinguish between different iron sources. Whether these different symbol designs are intentional, I do not know. While each map is clearly explained and well designed, in my opinion the overall work would benefit from greater consistency in the use of symbols.

A unique pair of figures are found in Chapter 1F that warrant special mention. Each combine a map and a graph to show patterns of construction of blast furnaces (Figure 9) and rolling mills (Figure 11) both geographically and also over time. The author notes the inspiration for these figures being the idea of a musical score. I found both the idea and the execution of these figures to be of compelling interest.

In summary, *Mastering Iron: The Struggle to Modernize an American Industry, 1800–1868* is a wonderfully written and produced book. I give it my highest recommendation for anyone with even the slightest interest in the history of the US iron-making industry. I look forward to future work by this author.

LAKE EFFECT: TALES OF LARGE LAKES, ARCTIC WINDS, AND RECURRENT SNOWS



By Mark Monmonier.

Syracuse University Press, 2012.

246 pages. $24.95, Hardcover

ISBN: 978-0-8156-1004-5

Review by: Bob Hickey, Central Washington University

As a long-time fan, I was looking forward to reading Mark Monmonier's *Lake Effect: Tales of Large Lakes, Arctic Winds, and Recurrent Snows*. It was particularly relevant, as I started reading the book in February at Chicago's O'Hare Airport—hoping for an uneventful flight west.

Over the years, I've read a number of Mark's books, going so far as to require *How to Lie With Maps* in my introductory cartography classes (Mark, if you're reading this, an updated version would be greatly appreciated!). *Lake*

Effect, like the others, was written for a public audience and is highly accessible.

When we think of weather in the US, there are three primary mechanisms: orographic precipitation in the West, frontal precipitation in the Plains and East, and the occasional hurricane. However, in the areas immediately to the east/southeast of the Great Lakes, there's another mechanism: lake effect snows. These are caused by cold northerly winds blowing across the Great Lakes which pick up (and dump) additional moisture. Snowfall can be significant, though often very localized. As such, they haven't received much attention outside the impacted areas.

Lake Effect is laid out in seven chapters, taking the reader from a discussion of what is lake effect snow through the mapping, forecasting, impacts, and long-term changes.

Chapter One comprises a quick description of lake effect snow and where it occurs.

Chapter Two is very much a cartographic history of the understanding of lake effect snows. It includes a brief history of (northeast US) meteorology. Interestingly, it wasn't until the 1960s that reasonably accurate maps of lake effect snow were available.

Chapter Three, like the previous two, takes a historical perspective—this time of weather forecasting in the region. A 1921 article by Mitchell and Day gave "perhaps the most concise, scientific explanation of lake effect snow" (60). However, any sort of prediction had to wait until the 1940s and the invention of radar. Even so, decent predictions required satellite imagery, a better understanding of physics, better ground radar coverage, and computers for the complex calculations. As of the writing of this book (2012), lake effect snow forecasting was still not as good as it could be. The resolution is 5 km, not good enough to accurately capture something as local as lake effect snow. Honestly, the description of the quality of forecasting was a surprise—I expect the Weather Channel to be spot on, especially in the short term.

Chapter Four starts with a discussion of how snowfall is measured—there are far more complications with this than one would initially think. It then goes on to discuss the impacts of considerable snow falling in a short period, focusing on different types of transportation: horse, rail, car, pedestrian.

Chapter Five is about local bragging rights. In other words, snowfall records (and some of the impacts of these record snows). Interestingly, there are two local awards given annually: The Golden Snowball to the city in Upstate New York (Buffalo, Syracuse, Rochester, Binghamton, Albany) with the highest annual snowfall and the Silver Snowball, an award started in 2004 which includes many smaller towns.

Chapter Six looks at long-term trends in lake effect snowfall. Over the past century, there appears to be a slight trend toward more snow; there are also links to the ENSO cycle. The chapter finishes with a nod toward global warming and a simple prediction: warmer temperatures will result in less snow.

Chapter Seven wraps things up with a proper geographical sense of place. This is then tied to a bit of a sales pitch for the region (four distinct seasons, winter recreation, etc). Clearly the author enjoys living in Syracuse!

Overall, this book is well written and gives a solid overview of the history and impacts of lake effect snow. As mentioned, it's written for the mass market, so there is considerable overlap between the chapters (repetition, repetition, repetition—a hallmark of teaching). Don't look for in-depth analyses of the weather/climate/physics/modeling etc.—that would quickly lose the intended audience.

That said, this book is a must-read for anyone interested in weather/climate. It details a unique (to the US, anyway) weather mechanism. I would also recommend it to anyone living near the Great Lakes—it will put the snowy life you live into perspective. As someone who fits into both groups (interested in weather and a former resident of the region), I found the book to be both entertaining and informative.

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Robinson, A. H., J. L. Morrison, P. C. Muehrcke, A. J. Kimerling, and S. C. Guptill. 1995. *Elements of Cartography, 6th Edition.* New York: John Wiley & Sons.

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

Articles in edited volumes: Name of author(s). Year. "Title of Article." In *Title of Edited Volume*, edited by [Editor's or Editors' names, not inverted], page numbers. City of Publication: Publisher's Name.

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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Cartography Associates. 2009. "David Rumsey Donates 150,000 Maps to Stanford University." *David Rumsey Map Collection*. Accessed January 3, 2011. **http://www.davidrumsey.com/blog/2009/8/29/david-rumsey-donates-150-000-maps-to-stanford**.

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