Interactive & Multiscale Thematic Maps: Preliminary Results from an Empirical Study

Robert E. Roth [a, *], Meghan Kelly [a], Nick Underwood [a], Nick Lally [b], Xinyi Liu [a], Kristen Vincent [c], Carl Sack [d]

[a] University of Wisconsin−Madison, Cartography Lab (USA), reroth@wisc.edu, mkelly22@wisc.edu, nunderwood3@wisc.edu, xliu636@wisc.edu
[b] University of Kentucky (USA), nicklally@uky.edu
[c] City of De Pere, Wisconsin (USA), kristen.vincent@snc.edu
[d] Fond du Lac Tribal & Community College (USA), carl.sack@fdltcc.edu

* reroth@wisc.edu

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Introduction

Here, we describe an empirical study on the design of interactive and multiscale thematic maps. Interactive or "slippy" web maps are commonplace today, supporting a user experience of a "map of everywhere" that can be panned around the globe and zoomed from global to local scales. Slippy maps have revolutionized the design and use of reference maps—as billions of mobile device owners now carry a reference map of the entire planet in their pocket—but is the same true for thematic maps? Evidence is building that more interactivity is not always helpful (e.g., Davies 1998; Keehner et al. 2008; Jones et al. 2009; Dou et al. 2010; Roth and MacEachren 2016). In this presentation, we examine if different thematic map types of the same attribute information lead to different user interaction strategies, and if particular interactions with these thematic maps lead to improved or incorrect understandings of the underlying spatial distributions.

Background

Thematic maps depict the distribution of one or several geographic phenomena, with the base reference information used as context for interpreting spatial variation in the thematic information (Tyner 2014). MacEachren and DiBiase (1991) organize thematic map types by two axes based on the visual metaphor they evoke about the represented phenomenon: discrete vs. continuous (i.e., how they exist in space) and abrupt vs. smooth (i.e., how they vary across space) (Figure 1). Choropleth maps evoke a metaphor of continuous and abrupt phenomena (e.g., congruently matching governmental activities and policies like tax rates), proportional symbol maps evoke a discrete and abrupt metaphor (e.g., economic sources of resources or sites of production), dot density maps evoke a discrete and smooth metaphor (e.g., individual people and social phenomena), and isoline maps evoke a continuous and smooth metaphor (e.g., spread of environmental or physical phenomena). Thus, thematic maps suggest at least four different ways for interpreting the same information based on their visual metaphor (Figure 1).

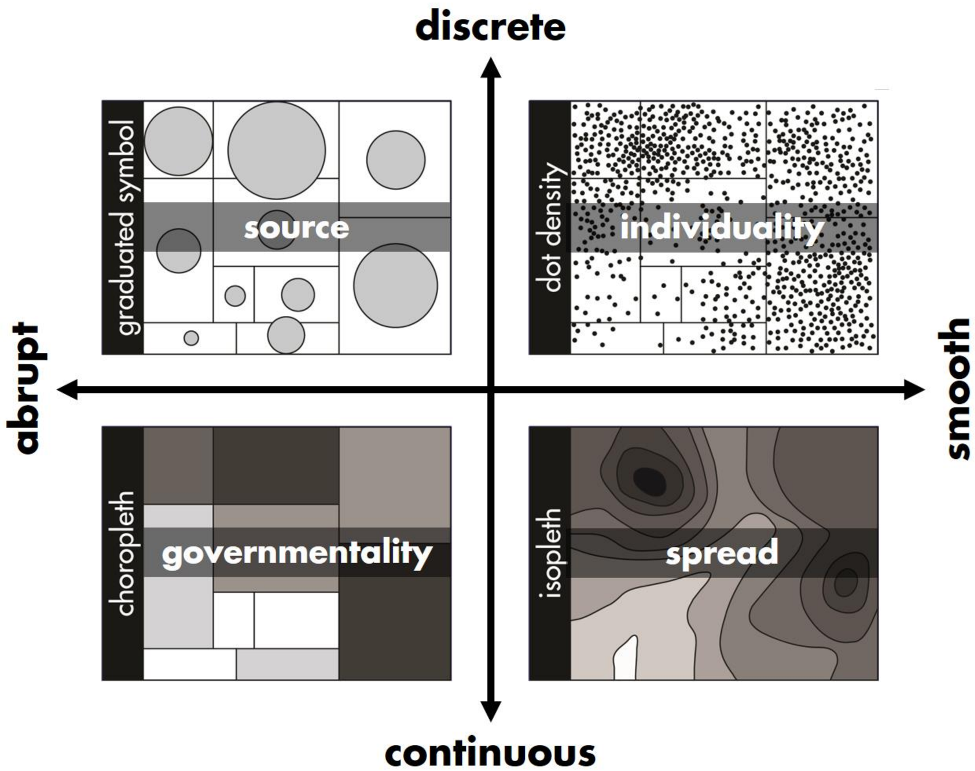

Figure 1: Thematic Map Types: Four different ways of looking at the same information. (MacEachren and DiBiase 1991)

The visual metaphor evoked by the thematic map type also potentially suggests different ways of interacting with the map. In prior work, we summarized existing taxonomies of interaction operators used in cartography and visualization (Roth 2012). Slippy maps commonly make use of the operators panning, zooming, and detail retrieval, and increasingly include more complex functions such as filtering, reexpression, and sequencing, among others. Interaction operators can be implemented in a range of interaction styles: panning and zooming often are applied through direct manipulation of the entire map (i.e., grab and drag to pan, pinch to zoom the entire map as a single field) or through direct manipulation of a linked widget (e.g., pan and zoom buttons) whereas detail retrieve often is applied through direction manipulation of individual map features (i.e., click or tap a feature) (Roth 2013). Thus, the visual metaphor of the thematic map, particularly the connotation of discrete and abrupt objects (individual map features) versus a continuous and smooth surface (the entire map as a single field), may influence interaction patterns with the map.

Method

We conducted an online study using the MapStudy experimental apparatus to understand how different visual metaphors in thematic maps result in different interaction strategies and geographic understanding. MapStudy is an interactive map survey application developed in the UW–Madison Cartography Lab that allows for interaction logging in addition to quantitative and qualitative survey measures (https://github.com/uwcartlab/mapstudy). We recruited 171 participants on Amazon

Mechanical Turk following a pilot with 74 participants. Participants were compensated $3.50 for participation, with the study requiring approximately 25 minutes.

We tested four experimental conditions: *choropleth*, *dot density*, *proportional symbol*, and *tinted isoline*. We removed a second factor on interface complexity after piloting to simplify the study. The thematic maps depicted synthetic twitter data and were presented at two levels of resolution navigable through zooming: 25 square U.S. counties (*overview)* and 625 square U.S. townships (25 per county; *details view*) (Figure 2). We selected Western Kansas for a consistent geography and expected low familiarity with recruited users. We only varied the visual variables associated with the thematic map, with tweets presented on an ordinal scale with five classes across map types. We held constant other aspects of visual design.

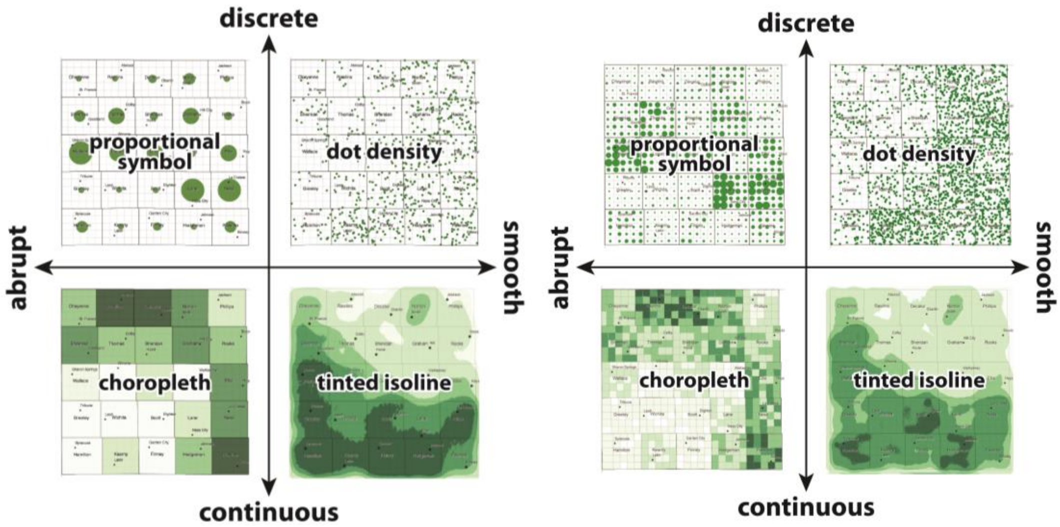

Figure 2: Comparison of multi-scale conditions included in the study. Left: *Overview*. Right: *Details view*.

Participants first completed a learning block introducing the provided operators, the legend design (but not the tested thematic symbolization), and the map reading tasks. Participants then viewed four "map reading" blocks showing different thematic map types, with four trials per block (16 trials total). The four trials were balanced to include two *compare* tasks and two *rank* tasks (only the analysis for the *compare* tasks is reported here) and two *elementary* tasks (requiring zooming into the *details view* to answer correctly) and two *general* tasks (which could be answered correctly by the *overview* alone). We captured dependent variables on correctness, self-reported confidence, and self-reported difficulty, in addition to interaction logs. We balanced the order of blocks and distributions within blocks using Latin Squares.

Results

Table 1 summarizes preliminary analysis of participant performance on *compare* tasks, separated by *elementary* and *general* map reading tasks. We did not find a significant difference in correctness across the four thematic map types for *general+compare* tasks that did not require zooming, suggesting that the type of thematic representation itself did not influence performance. However, we did find a significant difference in correctness for *elementary+compare* tasks that required interactivity, suggesting that the thematic map type did influence interaction patterns and resulting understandings of the underlying spatial distributions. Participants made the most errors on *general+compare* tasks using the dot density map, suggesting that the interactivity did not help or even misled map interpretation with dot density maps.

We found a significant difference in both self-reported confidence and self-reported difficulty for *elementary+compare* and *general+compare* tasks. The dot density and, to a lesser degree, the proportional symbol maps were rated lower than the choropleth and tinted isoline maps for both confidence and difficulty. Thus, participants generally were less comfortable with thematic maps evoking a discrete metaphor, regardless of interactivity. One possible explanation is that thematic maps evoking a discrete metaphor employ polygonal units for enumeration (here U.S. counties and townships) but represent attribute information using point rather than polygon symbols, thus requiring greater cognitive effort during map interpretation.

task	*elementary+compare*		*general+compare*	
measure	inferential test	p-value	inferential test	p-value
correctness	**χ^2=64.263**	**p=0.000**	χ^2=2.525	p=0.471
confidence	**H=12.858**	**p=0.005**	**H=14.886**	**p=0.002**
difficulty	**H=19.604**	**p=0.000**	**H=13.788**	**p=0.003**

Table 1: Differences in participant performance on *compare* tasks across thematic map type. We tested correctness using Chi-square. We tested self-reported confidence and difficulty using Kruskal-Wallis.

Table 2 summarizes preliminary analysis of participant interactions on *compare* tasks, also separated by *elementary* and *general* map reading tasks. We found a significant difference in total interactions across thematic map types for *elementary+compare* tasks, but not the *general+compare* tasks, again suggesting that the thematic map type influenced interaction patterns and resulting understandings of the underlying spatial distributions.

Notably, participants interacted with the dot density maps almost 30% more frequently than the next highest thematic map type, despite also responding with the least correct answers about spatial patterns within these maps. Further, we found a significant difference in the frequency of panning and zooming for *elementary+ compare* tasks, but not detail retrieval, with dot density and to a lesser extent proportional symbol maps receiving more pan and zoom interactions than the choropleth and tinted isoline counterparts. These added interactions potentially were needed to clarify patterns in the maps evoking a discrete metaphor, given the added cognitive effort needed to relate point symbols to polygonal features. Further, excessive panning and zooming interactions may suggest the participant is utterly lost, with more interactions inhibiting understanding of patterns in the thematic map (Roth & MacEachren 2016).

There was no significant difference in the frequency of detail retrieval for *elementary+compare* tasks. Dot density maps again received the most detail retrievals, although not a significant increase. However, choropleth maps received more detail retrievals than proportional symbols maps, the only interaction operator where the discrete metaphors did not receive more interactions. One possible explanation is that the abrupt metaphor evoked by a choropleth map better suggests that the map feature is “clickable” or “tappable” compared to the continuous metaphor of a tinted isoline map. A second explanation is that the participant groups are simply more familiar with slippy choropleth maps, given their increased use in popular media.

task	*elementary+compare*		*general+compare*	
interaction	inferential test	p-value	inferential test	p-value
total	**F=6.111**	**p=0.000**	F=2.450	P=0.063
pan	**F=5.688**	**p=0.001**	F=1.444	p=0.229
zoom	**F=3.437**	**p=0.017**	F=0.721	p=0.540
retrieve	F=1.226	p=0.299	F=1.660	p=0.174

Table 2: Differences in participant interactions on *compare* tasks across thematic map type. We tested differences in interaction frequency using ANOVA.

Outlook

Future steps in the analysis include: running post-hoc inferential tests to determine if dot density is a significantly different group for *elementary* tasks; examining unique interaction sequences in addition to the interactions in aggregate (i.e., do participants who incorrectly complete a task interact differently?); examining interaction effects with individual differences and preferences; triangulating findings with the more difficult *rank* tasks; and triangulating results with the qualitative feedback about different interactive and multiscale thematic maps.

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