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Cartographic Aspects of Animated Epidemiological Dashboards: A Human Subjects Experiment

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Introduction

Background / Motivation

The fast spread of the COVID-19 Global Pandemic encouraged many live online dashboards to track the virus in health geographical view. These dashboards visualized the COVID-19 trends using various symbolization and map forms to help people understand the pandemic and support policy responses.

Most COVID-19 dashboards had a critical role during the pandemic. However, some of those dashboards did not get many compliments. Instead, the cartographic design choices of those dashboards received much criticism (Hannen 2020, Juergens 2020, Mooney and Juhasz 2020, Geospatial @ UCSF 2020, Yoo and Kronenfeld 2020). In addition, map form and symbolization can impact map interpretation (Field 2020), and poorly built disease maps can lead to misinterpretation of local disease levels, regional clusters, and temporal trends (Boscoe & Pickle, 2003). Appropriate symbolization helps people understand complex datasets more efficiently, but inappropriate symbolization can lead to misinformation about the disease. Therefore, measuring how to create an effective animated disease map is important. In addition, prior research has suggested using population cartograms in disease maps, so examining how well population cartograms communicate case counts, rates, and population simultaneously is also essential.

A human subjects experiment was conducted to assess the advantages and disadvantages of various symbolization in animated maps and cartograms. The experiment tested subjects' ability to recall locations of peak rates and counts from an animation of a hypothetical epidemic consisting of three primary "waves."

Research Questions

This paper attempts to answer several research questions by examining human subject responses to animated COVID-19 dashboards:

1. Do people perform better/differently with cartograms vs. maps?

2. Does prior instruction on cartogram interpretation influence accuracy?

3. Do people visually notice outliers more readily from visual size vs. color?
4. Does number of districts and complexity of spatio-temporal pattern influence performance?
5. Do people perform better with redundant symbolization?
6. Does cartogram encourage people to notice small but densely populated districts?
7. What type of animated map are people most comfortable with, and why?

Method

Subjects

Survey participants were recruited using the Prolific platform (https://prolific.co). Survey respondents were required to be fluent in English, and an equal number of male and female participants were recruited. This study had IRB exemption because no personally identifiable information was collected. There were 96 subjects in survey round 1 and 107 in round 2. We identified potential factors that might indicate invalid responses. Those factors help screen out any suspicious responses that might ruin the result. The screening methods were:

- Respondents who didn’t answer some questions
- Respondents who answered preliminary map questions incorrectly

There were 88 people in round 1 and 106 in round 2 after the screening.

Survey Instrument

The survey was created from scratch using web technologies, and responses were saved to a Google Workspace on survey completion. Static and animated disease maps were embedded into the survey form in a modular fashion so that different subjects received the same questions but different maps/animations. Developing the survey form from scratch allowed greater control. For example, we ensured that each participant viewed each animation only once and could not repeat or go back to view specific points in time.

Case data were developed for a 100-day period for districts in seven distinct regions: Canada, Europe, western Europe, and the states of New York, Colorado, California, and Iowa. Three seed districts were selected in each region as peak districts for each of the three waves, and two outlier districts were selected in each region to surge slightly later than the first and third peaks. These two outliers allow identifying minor aberrations from the large pattern, which helps assess change blindness.

The survey contained three main sections: preliminary questions, main questions, and preference questions. Two rounds of the survey were conducted, with instruction on cartograms and elicitation of preferences in the second round only. Comparison between rounds enabled assessment of the effect of instruction on accuracy.

Preliminary Questions

The purpose of the preliminary questions was to familiarize subjects with general concepts and map forms. In round 1, three questions were asked to give subjects background knowledge about bubble maps, choropleth maps, and cartograms. In the second round, three additional questions provided instruction on interpreting bubble cartograms, choropleth cartograms, and colored bubble cartograms. Seven more questions tested the key concept of interpretation of size on bubble cartograms (Figure 1):

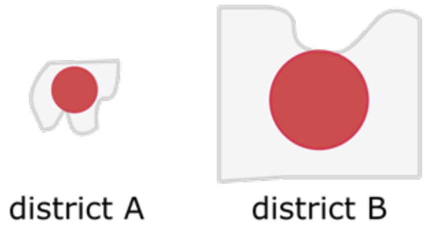

Figure 1: Sample of stimulus presented to help subjects understand the combination of symbol sizes (case counts) and cartogram district sizes (populations). Subjects were asked to determine the district with higher case rates per population.

Main Questions

The main section consisted of a series of animated maps of five regions. For each region, subjects were asked to recall the location of the highest peak of case rates during each of three waves.

For example, Figure 2 shows the temporal patterns used to construct the animated map for California. Based on the patterns, subjects should choose San Francisco (e) as the answer for wave 1, Fresno (b) as wave 2, and Los Angeles (c) as wave 3, while San Diego (d) acts as an outlier and provide complexity.

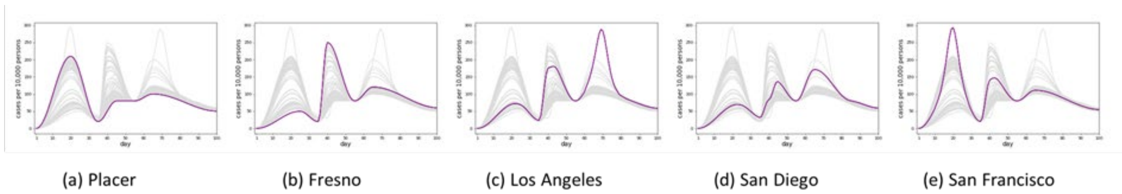

Figure 2: Graphs of temporal patterns were used to construct animated maps of hypothetical COVID-19 case rates in California.

Preference Questions

At the end of the survey, subjects in round 2 were allowed to choose one animated map form to view real data on the COVID-19 epidemic in the USA. Options were provided as static images (Figure 3). Subjective reasons for their choice were elicited by asking which map was best for three different purposes, why they chose the map form that they did, and after viewing the USA animation, whether they were satisfied with their choice or would pick a different map type after viewing the animation.

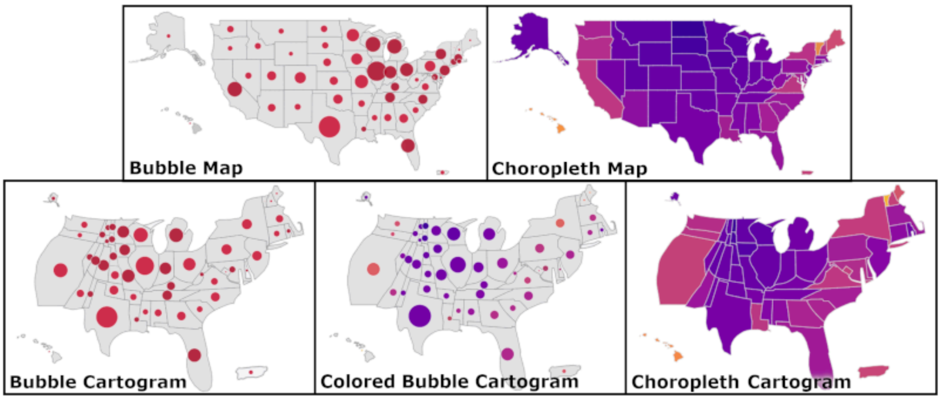

Figure 3: Options presented to subjects for choice of animated map of COVID-19 cases in the USA.

Analysis

Survey responses for the main section were analyzed using several methods based on the question section. Overall, the accuracy rates for all questions except qualitative questions were calculated to see the general results of the survey. Comparisons were made between map types and rounds. The preliminary questions section calculated accuracy rates to examine how people understand various map forms and symbologies. Also, responses were screened based on this accuracy rate. For the main questions section, 2-sample difference of proportions tests were used to assess whether accuracy rates differed statistically for two map types. Binomial Logistics Regression was used to determine interaction effects, specifically whether in-depth instruction on cartogram interpretation in round 2 altered the influence of map form on accuracy rates. Analysis methods based on each region and research questions are shown in table 1. Furthermore, the accuracy rate of cartogram questions was compared with subjects' accuracy rates for preliminary cartogram questions to find preliminary cartogram questions helped accuracy rates for cartogram questions in the main section.

Table 1.

Research Question	**Region(s)**	**Type of Analysis**
Q1: Do people perform better/differently with cartograms vs. maps?	Canada	2-sample difference of proportions
Q2: Does prior instruction on cartogram interpretation influence accuracy?	Canada, State of New York	Binomial Logistic Regression
Q3: Do people visually notice outliers more readily from visual size vs. color?	Iowa	2-sample difference of proportions
Q4: Does number of districts and complexity of Spatio-temporal pattern influence performance?	Europe	2-sample difference of proportions
Q5: Do people perform better with redundant symbolization?	New York	Binomial Logistic Regression

Q6: Does cartogram encourage people to notice small but densely populated districts?	Colorado, California	2-sample difference of proportions
Q7: What type of animated map are people most comfortable with, and why?	USA	Chi-Squared Contingency Table Test

Qualitative responses for questions in the preference section were categorized according to general justifications (i.e. functional preferences) for selecting a given map type. The different categories were then cross-tabulated to determine any association between functional preferences and preferences in map type.

Preliminary Results and Discussion

In the preliminary questions, subjects were able to accurately interpret static maps of all map forms, with over 94% accuracy rates for all except the choropleth cartogram and colored bubble cartogram, which had accuracy rates of 73.5% and 82%. Further, on simple static two-district maps that compare higher rates in cartograms, 94% of subjects could identify districts with higher rates.

From the main analysis, this study found that instruction in cartogram interpretation and practice with simple static two-district cartograms (round 2) impacted subjects' accuracy rates and attention. Cartograms effectively drew attention to densely populated districts. For example, If a densely populated district was the correct answer, subjects given cartograms were more likely to get the right answer. Conversely, when the correct answer was sparsely populated districts, subjects given cartograms were less likely to get the right answer. Moreover, prior instructions emphasizing the importance of population improved response accuracy on cartograms and regular maps.

Survey results also indicate that bubble cartograms were ineffective at communicating case rates (cases per population) with animations. For example, subjects did not perform better at identifying districts with peak rates on animations of bubble cartograms than bubble maps without population information.

In terms of visual perception, bubble size and choropleth color were perceived and remembered with equal accuracy (90% vs. 93.9%) when the bubble map represented cases and the choropleth map represented rates. This suggests that animated maps perceive size and color with equal salience.

The last thing that this study found is that the number of districts affects accuracy rates. When comparing the Western Europe map (fewer districts) and the All Europe map (more districts), subjects had higher accuracy rates with the Western Europe map in waves 1 and 3, which means that it is easier to follow the disease patterns with fewer districts.

In animated epidemiological dashboards, this human subject experiment found that subjects' accuracy rates are affected by pre-instructions, number of districts, symbolizations, and map forms. These findings suggest that epidemiological dashboards should carefully consider map forms and symbolizations because those factors impact map consumers' interpretation and lead to misinterpretation of local disease levels, regional clusters, and temporal trends.

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