Spatial Knowledge and Information Canada, 2019, 7(1), 5

Web Maps for Global Data Visualization: Does Mercator Matter?

SAM LUMLEY
Department of Geography
School of Environment
McGill University
sam.lumley@mail.mcgill.ca

RENEE SIEBER
Department of Geography
School of Environment
McGill University
renee.sieber@mcgill.ca

ABSTRACT

The Mercator projection has become a standard across web mapping platforms, but has long been considered inappropriate for global data display due to its distortion of high latitude areas. With the ever-rising popularity of web maps, the Mercator projection has seen a resurgence in its use for spatial data visualizations. In this study we investigated the implications of the area distortion effects of the Mercator projection for public data interpretation. We recruited 120 participants via Amazon's Mechanical Turk platform to complete an online survey assessing their ability to identify and account for the distortion effects. Participants were asked to estimate the areas covered by five colored regions on a global map, having been split into a control group using an equal-area projection and a treatment group using a Mercator projection. On average, participants did not discount for the projection and their data interpretation differed between the two conditions as a result. Our findings provide an empirical basis for the distortion effects of the Mercator projection currently used in web maps, and further implicate its appropriateness for displaying global data. More broadly, they introduce experimental methods for research exploring cartographic biases in non-expert groups.

1. Introduction

1.1 Web maps for data visualization

Web map visualization describes the interactive display of geographic information on a computer-based map (Kraak & Brown, 2014). By giving users an intuitive schema for navigation, web maps represent a popular communication tool for sharing spatial information (Elwood, 2011; Johnson & Sieber, 2012). Further, the development of map tiling services over the past decade has dramatically reduced the computational demands for data retrieval and display (Haklay, Singleton, & Parker, 2008), enabling user-friendly interaction and serving the information seeking Mantra: "overview first, details on demand" (Shneiderman, 1996).

As a result, there is a growing adoption of web mapping applications, such as Google Maps, OpenLayers and Mapbox APIs, in public data portals and interactive maps (Batty, Hudson-Smith, Milton, & Crooks, 2010). This resurgence demands further research into the perceptual implications of the Mercator projection's area distortions. Understanding how such representational features influence public data interpretation represents a critical issue in GIScience, and will be key to improving cartographic communication more generally.

1.2 Mercator in web maps

The Mercator projection has become the standard across web mapping applications (Battersby, Finn, Usery, & Yamamoto, 2014). The preservation of angles (conformality) and universally upward pointing north (cylindricality) make it ideally suited for street mapping services (Strebe, 2012). The variant used in web mapping represents the earth as a square at its lowest zoom level by truncating each pole by 5°. These properties come at the expense of area distortions that increase from the equator to the poles.

While mapping platforms provide a powerful and convenient tool for data visualization, past research has shown that even experienced users can struggle to compensate for distortions when making on-the-spot judgements (Downs & Liben, 1991; MacEachren, 2004). The "Mercator Effect" predicts that people overemphasize the importance of the enlarged high latitude regions (Saarinen, 1988), which can lead to an inaccurate interpretation of any global data being overlaid. Critical geographers further argue that the distortion and orientation effects have served to reinforce European colonialism (Harpold, 1999), and more recently new forms of 'digital imperialism' (Farman, 2010).

For this reason, the Mercator projection has long been renounced for use in scientific visualization on the grounds that its area distortions mislead map readers (Robinson, 1966). Despite this turbulent history and recent resurgence, there are still relatively few empirical studies investigating the cognitive implications of map projections for data display (Battersby et al., 2014). Further, it is unclear whether past results remain relevant (Montello, Waller, Hegarty, & Richardson, 2004), particularly in light of recent mapping technologies (Lapon, Ooms, & Maeyer, 2017). Digital interfaces offer new opportunities and new modalities through which people can engage with spatial data (Haklay et al., 2008). The resulting shifts in use warrant further investigation.

A recent body of research has begun to explore these implications. Notably, (Battersby & Montello, 2009) investigated the influence of map projections on global-scale cognitive maps. Their results from 194 student participants' area estimations of world regions suggested that projection choice had a lower-than-expected impact on cognitive maps, a finding further explicated in a follow up review by Battersby et al. (2014). Aside from a study on map projection preferences (Šavrič, Jenny, White, & Strebe, 2015), most recent experimental research on map projections has been focused on academic or expert populations. As the number of web mapping applications used to display scientific data rises, it will be increasingly important to understand the implications of projection choices in digital interfaces for non-expert audiences (Nocke, Flechsig, & Bohm, 2007; Slocum et al., 2001), a primary objective of the present study.

1.3 The present study
This study assesses the influence of the Mercator projection on area estimation and data interpretation in non-expert audiences. Specifically, we were interested in whether people identify the distortions, and if they do, how able they are to account for them. This question was addressed through an online experimental survey exploring impacts on area-based judgements about global geospatial data. To this end, we advanced two hypotheses: (1) individuals making on-the-fly judgements about spatial data presented on a map are unlikely to identify or correct for projection distortions and; (2) even if individuals are aware of the distortions, they will struggle to accurately convert back to the corresponding areas.

2. Methods and Data:
2.1 Participants
Participants (N = 120) were recruited using Amazon's Mechanical Turk online hiring platform (Amazon, 2014). Mechanical Turk is a well-established recruitment tool used widely in social science research (Berinsky et al., 2012; Litman et al., 2017), and has been implemented successfully in cartographic research more recently (e.g. Retchless & Brewer, 2015; Šavrič et al., 2015). All of our respondents were adults

living in the United States and participated through a Qualtrics online survey. Our sample had a mean self-reported age of 35 years (SD = 13.0), with 29% female and 42% with a bachelor's degree as their highest attained level of education. Participants were offered $1.00 for completing the survey, plus a $0.50 performance-based bonus. After eliminating responses with incomplete or unusable answers, we retained 113 valid responses.

2.2 Design

Participants were randomly assigned to one of two conditions: a treatment condition using a Mercator version of the map (N = 60) and a control condition using an equal-area (Lambert cylindrical) version (N = 53). The control map projection was chosen because areas could be compared at face-value across the image, while also being a commonly used projection (Šavrič et al., 2015).

The data used in the map visualizations was derived from a global temperature dataset downloaded from the University of East Anglia Climatic Research Unit's website (Jones, New, Parker, Martin, & Rigor, 1999). The data was interpolated and color-quantized to produce five lateral regions that emphasized the Mercator Effect, and then overlaid on a country outline map. Figure 1.0 shows a greyscale version the two map projections given to participants. We used the Image Color Summarizer tool (Krzywinski, 2016) to calculate the face-value areas for each shaded region, measured as a percentage of the entire image, such that the face-value areas for the control map represented the undistorted area values.

2.3 Procedure

To investigate the effects of projection choice on data interpretation, we designed an area estimation and threat perception task. Participants were shown a global-scale map with categorical data displayed (Figure 1.0), which they were told represented the presence of five different pollutants over the earth's surface. This construction corresponded closely enough to a relatable real-world example, but was abstract enough for participants to engage without strong prior perceptions influencing their responses (a common problem encountered during our pilot surveys which used a temperature labelling scheme). Participants were asked to estimate the total area covered by each of the five pollutants. Further interpretation of the data was evaluated by asking respondents to choose which of two particular colored pollutants they perceived to be a greater threat to the earth.

Participants were next given a short explanation of how different projections unavoidably distort areas and/or shapes displayed on maps. After this briefing, it was hoped that some participants would decide that their previous area judgements had been be influenced by the projection they had been given. They were then shown a blank version of both projections and asked which one they thought was more suitable for an area estimation task, and given the option to alter their original estimates in light of the briefing. Participants in the treatment condition changing their estimations would provide evidence that they had identified and attempted to account for the Mercator Effect.

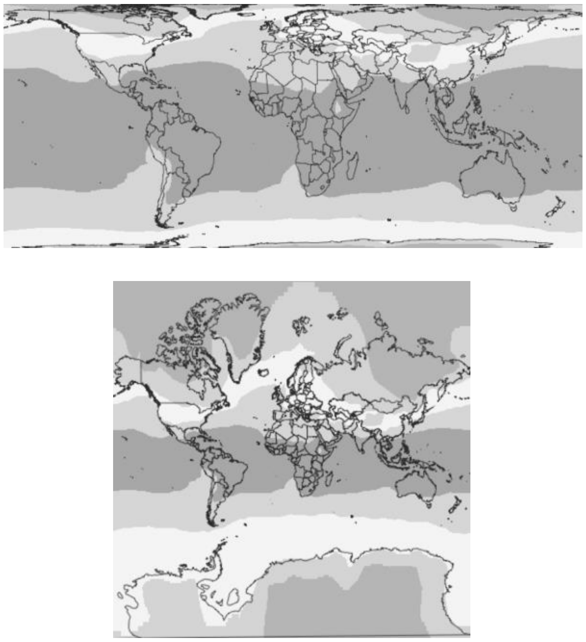

Figure 1.0: The equal-area (top) and Mercator (bottom) data visualizations given to participants via an online survey.

3. Results

3.1 Area estimation

We tested for the effects of projection type using independent-samples t-tests to compare the equal-area and Mercator conditions across the five area estimations made by participants. We found a significant difference across all the regions. Specifically, participants overestimated the areas which had been enlarged by the Mercator projection, in line with face-value area judgements, as shown in Table 1.0. Similarly, the control condition estimates corresponded closely with the face-value measurements for the equal-area projection. Surprisingly, the answers to the second area estimation question did not differ significantly from the original answers; while some participants in both categories chose to alter their answers, most stuck with their original estimates.

Table 1.0: *Comparison of the mean estimate and face-value proportions (%) across conditions.*

	Equal-area		Mercator	
Region	Mean estimate	Face-value	Mean estimate	Face-value
A	7.5	4.0	23.3	16.2
B	10.2	7.2	17.7	15.0
C	13.3	15.5	20.1	23
D	26.7	27.5	18.2	19.
E	42.3	45.9	20.7	26.0

3.2 Data interpretation and map suitability

A chi-square test of independence was used to examine the relationship between data interpretation and projection choice. The difference between conditions was significant, $\chi 2$ (1, N = 113) = 13.58, $p < 0.01$. In particular, 17% of participants in the equal-area condition (N = 53) perceived pollutant A to be a greater threat than pollutant E, compared to 50% in the Mercator condition (N = 60). A chi-square test was used to test for differences in the answers to the map suitability questions. No significant difference was found between conditions; participants did not judge one projection to be better than the other for making area judgements.

4. Conclusion

The results from the area estimation and data interpretation tasks indicated that participants' judgements were significantly affected by the choice of projection. Specifically, participants took the maps at face-value and interpreted the data accordingly. This result was corroborated by responses to follow-up questions, which suggested that participants identified the Mercator projection as being equally appropriate to the control projection for area estimation tasks, as well as the fact that they chose not to adjust their answers to the second part of the survey.

Further work would be necessary to refine the methods used in this study. It is possible that some of the documented effects could have been observed if participants had not fully understood the wording of the questions. Additionally, there were several unaddressed confounds between the two conditions which could have contributed towards the observed differences, such as the image dimensions and differences in granularity between the maps which arose due to scaling deformations. Despite these limitations, the central result, that the Mercator projection biases global data interpretation, has concrete implications for geovisualization and GIScience research.

This study has provided empirical evidence for the Mercator Effect in web maps. We found that individuals were unlikely or unable to identify and re-project area data displayed on a Mercator projection to corresponding areas on the earth's surface, corroborating past research (Monmonier, 1996; Robinson, 1966). Our framing of the tasks deliberately pointed towards the potential for misinterpretation of data in real-world decision-making scenarios. More broadly, the results emphasize the strong influence of cartographic design on public interpretation of geographic information. Further work should critically assess efforts to address the Mercator effect in web maps, such as the inclusion of gridlines, alternative web mapping projections and adaptive maps (Jenny, 2012). Further GIScience research can continue to broaden our understanding of the complex relationships between visual representation and perception of geospatial information.

Acknowledgements

This study was completed in the Department of Geography at McGill University under the supervision of Professor Renee Sieber and Dr. Jin Xing, both of whom I thank for their support and guidance. We also thank the two anonymous reviewers for their helpful comments on earlier drafts of the manuscript.

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