Title
Data Visualization as a Domain to Research Areas in Cognitive Science

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How people are able to turn information in the environment into meaning is a critical question for cognitive science. That environment is increasingly data-driven. Using data to inform decisions and improve understanding of the world is a valuable component of critical thinking, and serves as the foundation of evidence-based decision making. Designing graphical representations can make those data more accessible, such that users may engage the visual system and capacity for visual pattern recognition to discern regularities and properties of data. We ultimately want to understand the connection between the initial perception of data visualizations and conceptual understanding of information. Data visualizations, broadly, are the representation of recorded values in visual form, including scientific visualizations such as brain scans, or live visualizations such as stock market monitoring; the work discussed through this symposium is of the type used in science, business, and medical settings to display data abstractly.

Lessons from cognitive science have been used to improve data visualization designs. However, the relationship between cognitive science and data visualization is hardly one-sided. Data visualizations can be used to learn more about cognition itself (Fisher, Green, Arias-Hernandez, 2009). For example, a study about the memorability of data visualizations shows that text and visual semantic redundancy improve recall and recognition (Borkin *et al.*, 2015). Similarly, studies of visual routines for reading data displays reveal that individuals show idiosyncratic feature preferences, such as attentional biases for larger or smaller objects, that guide visual perception (Michal & Franconeri, 2017). The reciprocity between data visualization and cognitive science is a guiding theme for this symposium, which also serves as an introduction of data visualization as a fruitful research topic for the Cognitive Science Society in its 40th Meeting, themed "Changing Minds."

Samples of Research Areas in Cognition

In this symposium we discuss lessons for cognitive science from data visualizations spanning lower level processes through to higher level cognition, namely

- Perception
- Attention
- Cognitive development

Using data visualization as a guiding domain is valuable as it can be queried from multiple levels of analysis; it is also practically valuable because data visualizations support actual decisions. Knowing how those visualizations work has immediate practical consequences and cumulative theoretical value.

Using such a domain -- practically useful and theoretically extensible -- offers an opportunity for unifying presently disjointed research areas in cognitive science.

Robert Goldstone: The mutual shaping of visualizations and perception

One of the most promising ways to teach and learn difficult concepts is to take advantage of the millions of years of "evolutionary research and development" that has gone into the development of human perceptual systems. Our laboratory's research illustrates some of the pitfalls and peaks of using visualizations to learn about challenging concepts in systems thinking, algebra, neuroscience, and statistics (e.g. Marghetis, Landy & Goldstone, 2016).

One of the important messages from this research is that visualizations should be shaped in a way that takes into account that people implicitly and strategically shape their own perceptual systems to better fit the requirements of visualizations.

Karen Schloss: Color inference and its role in visual communication

When people interpret data visualizations, they are faced with a task of visual reasoning –making conceptual inferences from visual information. People are more effective at this task when the encoded mappings between concepts and visual features match their predicted mappings, but the question is, what determines their predicted mappings? We addressed this question by studying how people interpret color-coding systems in information visualizations. We were specifically interested in cases where there are extensive one-to-many and many-to-one mappings in the color-concept associations (i.e., one color is associated with many concepts, and many colors are associated with the same concept). Evidence suggests people resolve these conflicts by performing assignment inference, analogous to solving an assignment problem in optimization, to determine how colors map onto concepts (Schloss *et al*., 2018).

Jessica Hullman: Prior Knowledge and Expectations

We are rethinking the role of prior knowledge and expectations in visualization interaction by examining how comprehension of data changes when a person can directly visualize their expectations alongside data (Hullman *et al.*, 2018). For example, we've studied how predicting data and then seeing the actual data alongside your prediction impacts one's ability to remember the data a short while later as well as to make predictions about similar future scenarios. We've compared the impacts of eliciting and representing predictions in a visualization to a text format to better understand what affordances visualizations may bring for allowing a person to repair gaps in their existing "mental models" of a phenomena. In the process we've explored how to most naturally elicit people's expectations given different sets of graphical encodings, including lines and distribution plots.

Jennifer Kaminski: Visualization and Symbols for Math Learning

We are studying how visual representations of mathematical concepts influence student learning, and students' ability to apply knowledge (Kaminsky & Sloutsky, 2013).

In several experiments, elementary school children were taught and tested on mathematics topic such as reading bar graphs; the inclusion of extraneous perceptual information hindered children's learning and performance. These findings underscore the importance of designing instructional material in which visual information helps communicate the defining relational structure of the mathematics while minimizing extraneous detail.

Conclusion

The practical purpose for a data visualization is to support decision making or offer insights. We will discuss open problems for in an applied/translational space, including how to instruct students to use data visualizations.

Conceptually, our panel shows how considerations spanning perception through education/instruction are all invaluable for understanding the connection between comprehending visualizations and decision making or insight generation.

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