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Thinking Graphically: Connecting Vision and Cognition During Graph Comprehension

Raj M. Ratwani
George Mason University

J. Gregory Trafton
Naval Research Laboratory

Deborah A. Boehm-Davis
George Mason University

Task analytic theories of graph comprehension account for the perceptual and conceptual processes required to extract specific information from graphs. Comparatively, the processes underlying information integration have received less attention. We propose a new framework for information integration that highlights visual integration and cognitive integration. During visual integration, pattern recognition processes are used to form visual clusters of information; these visual clusters are then used to reason about the graph during cognitive integration. In 3 experiments, the processes required to extract specific information and to integrate information were examined by collecting verbal protocol and eye movement data. Results supported the task analytic theories for specific information extraction and the processes of visual and cognitive integration for integrative questions. Further, the integrative processes scaled up as graph complexity increased, highlighting the importance of these processes for integration in more complex graphs. Finally, based on this framework, design principles to improve both visual and cognitive integration are described.

Keywords: graph comprehension, diagrammatic reasoning, eye tracking

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Imagine a health scientist attempting to contain the flu epidemic. The scientist may study a population density graph (similar to Figure 1) depicting the number of flu cases by county. To allocate the limited flu vaccine, the scientist may want to know the specific number of cases in a particular county or the general trend of infected cases. What cognitive and perceptual processes are used to extract these different types of information from a graph?

Specific information extraction involves searching for a specific data point and determining the quantity represented by the data point. Integrating information, which is required to determine the trend in a graph, demands the extraction of multiple data points and interpretive processes to combine this information into a coherent representation. The goal of this article is to examine the cognitive and perceptual processes used to extract specific information and to integrate information, with an emphasis on the integration process. We elaborate on existing frameworks of integration and provide guidelines to facilitate integration in graphs.

Specific Information Extraction

Most theories of graph comprehension have focused on the cognitive and perceptual processes underlying specific information extraction from graphs. Specifically, task analytic theories (Kosslyn, 1989; Lohse, 1993; Pinker, 1990) provide process description of specific information extraction with a focus on relatively simple graph types (i.e., bar and line graphs). These theories are remarkably consistent, suggesting the following stages of processing: (a) pattern recognition occurs, whereby graph readers encode the visual array and identify visual features of the graphical pattern; (b) conceptual relations are determined, giving rise to the quantitative meaning of the visual features; and (c) referents of the graph are related to the encoded visual features.

Several empirical studies have provided support for the task analytic theories' account of specific information extraction by examining the specific processes that comprise the general stages outlined previously (Carpenter & Shah, 1998; Lohse, 1993; Peebles & Cheng, 2003). First, parts of the question may be read multiple times (Peebles & Cheng, 2003). Next, the participant searches for the specific information on the graph (Stage 1), shifting from the axes to the main part of the graph and back again (Stage 2; Carpenter & Shah, 1998; Lohse, 1993; Pinker, 1990).

Raj M. Ratwani and Deborah A. Boehm-Davis, Department of Psychology, George Mason University; J. Gregory Trafton, Naval Research Laboratory.

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Correspondence concerning this article should be addressed to Raj M. Ratwani, Department of Psychology, George Mason University, MSN 3F5, Fairfax, VA 22030-4444. E-mail: rratwani@gmu.edu

Thinking Graphically Connecting Vision And Cognition

Julia Schneider

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