

## Thinking Graphically: Connecting Vision and Cognition During Graph Comprehension

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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).

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# Thinking Graphically Connecting Vision And Cognition

**Margaret S. Archer**



## **Thinking Graphically Connecting Vision And Cognition:**

**Thinking Graphically: Connecting Vision and Cognition During Graph Comprehension**, 2008 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 three 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

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The world perceived at the visual level is constituted not by objects or static forms but by processes appearing imbued with meaning As G Kanizsa stated at the visual level the line per se does not exist only the line which enters goes behind divides etc a line evolving according to a precise holistic context in comparison with which function and meaning are indissolubly interlinked Just as the meaning of words is connected with a universe of highly dynamic functions and functional processes which operate syntheses cancellations integrations etc a universe which can only be described in terms of symbolic dynamics in the same way at the level of vision we must continuously unravel and construct schemata we must assimilate and make ourselves available for selection by the co ordinated information penetrating from external Reality Lastly we must interrelate all this with the internal selection mechanisms through a precise journey into the regions of intensionality In accordance with these intuitions we may directly consider from the more general point of view of contemporary Self organisation theory the network of meaningful programs living at the level of neural systems as a complex one which articulates and develops functionally within a coupled universe characterised by the existence of a double selection external and internal the latter regarding the universe of meaning This network gradually posits itself as the basis for the emergence of natural and meaningful forms and the simultaneous if indirect surfacing of an I subject as the basic instrument in other words for the perception of real and meaningful processes of objects possessing meaning aims intentions etc above all of biological objects possessing an inner plan and linked to the progressive expression of a specific cognitive action [Conference Proceedings](#) ,2002 **Resources in Education** ,1997 [Documentation Abstracts](#) ,1987 **Thinking and Seeing** Daniel T. Levin,2004 A collection in which the contributors draw on diverse areas of cognitive science to examine the difference between actual and presumed visual cognition [Artificial Intelligence Abstracts](#) ,1990 [Government Reports Annual Index](#) ,1988 **Subject Guide to Books in Print** ,2001

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