

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

Howard Levine, Howard Rheingold



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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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Eye Tracking and Visualization Michael Burch, Lewis Chuang, Brian Fisher, Albrecht Schmidt, Daniel Weiskopf, 2017-01-20 This book discusses research methods and recent developments in the interdisciplinary field that spans research in visualization eye tracking human computer interaction and psychology It presents extended versions of papers from the First Workshop on Eye Tracking and Visualization ETVIS which was organized as a workshop of the IEEE VIS Conference 2015 Topics include visualization and visual analytics of eye tracking data metrics and cognitive models eye tracking experiments in the context of visualization interfaces and eye tracking in 3D and immersive environments The extended ETVIS papers are complemented by a chapter offering an overview of visualization approaches for analyzing eye tracking data and a chapter that discusses electrooculography EOG as an alternative of acquiring information about eye movements Covering scientific visualization information visualization and visual analytics this book is a

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disciplines including geography and education The Spatial Cognition conference offers one of the few forums for consideration of the issues spanning this broad academic range

The Cognitive Connection Howard Levine, Howard Rheingold, 1987 Discusses the differences between natural language and programming languages looks at mathematical logic and describes the future of computer programming

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Art Therapy, 1989 *Psychology of Thinking* David A. Contreras, 2010 Psychology has long influenced our thinking about teaching and learning However earlier influences of psychology on education were more about not thinking than what we now consider to be the thinking processes necessary for life and work in the 21st century The narrow boundaries of behaviourism have given way to the complexities of critical thinking creativity analysis connection making and the self management skills of decision making planning and self evaluation This book focuses on raising the awareness of scientists and other readers to a form of thinking called design thinking as well as major findings regarding the affective motivational and cognitive consequences of insurmountable obstacles and their impact on the thinking process

[A Resource Guide for Teaching K-12](#) Richard D. Kellough, 2007 Practical and thorough this engaging resource guide truly practices what it preaches hands on activities rich research based performance driven teaching With its hallmark practicality the text uses case studies sample units with lessons opportunities for practice and feedback and activities to equip future teachers with numerous examples of best practices current research findings and proven teaching strategies This is truly one of the most comprehensive texts on the market today made even better in this latest edition with its organization designed around the decision making phases of instruction

A Field Guide to Using Visual Tools David Hyerle, 2000 Visual tools are explored including brainstorming webs task specific organizers and thinking process maps

Student Successes With Thinking Maps(R) David Hyerle, Larry Alper, Sarah Curtis, 2004-06-04 Foreword by Pat Wolfe Following a presentation of the what why and how of Thinking Maps the reader is treated to a panoramic view into schools that have successfully used this unique tool kit to bridge the gap from research to practice All are worthy models to examine and follow as schools focus on continuous growth for all through both individual and school improvement The book is a must read Marti Richardson President National Staff Development Council How do we support all learners to use thinking skills across disciplines Visual organizers reflect what we know of how the brain processes stores links and builds new learning In this new resource David Hyerle the

originator of Thinking Maps shares stories from teachers principals and trainers who have adopted the maps to increase student achievement and revitalize learning communities Among the specific successes here teachers and leaders will find ways to use Thinking Maps as a visual language and a frame of reference to Help all students access difficult content areas Provide a bridge to overcome cultural disconnects between teachers and learners Spur higher order thinking and discussion even in young children Offer a tool to assess content understanding in students with limited English Provide a means for students to think and talk more deeply about mathematics Provide prompts and organizers for more effective writing Offer new learning supports for students with differences Provide a common learning community toolbox for teachers students and parents Integrate learning across grades and subjects and from prior knowledge to new learning Students teachers and administrators have proven that thinking maps are a key to improving performance by students across cultures and languages raising the quality of instruction and offering new pathways to sustain constructive conversations within schools

Seeing and Visualizing Zenon W. Pylyshyn,2003 How we see and how we visualize why the scientific account differs from our experience **Handbook of Applied Cognition** Raymond S. Nickerson,1999-07-09 Cognitive psychology is the basis of many applications in almost every area of technology business industry and education This book provides workers in applied arenas with presentations of research aimed directly at the problems and issues that confront them It will cover key areas including business and industry computers and technology education and information and health and law **Mapping Thoughts** Thomas Kevin Gillespie,1991 *Cognitive Processes in Spelling* Uta Frith,1980 **Computers as Cognitive Tools, Volume Two** Susanne P. Lajoie,Susanne Lajoie,2000 Volume II provides the reader with examples of state of the art technology based research in the fields of education training Researchers represented include computer scientists cognitive scientists educ psychologists instructional psychologists *Investigating Visual Literacy* International Visual Literacy Association. Conference,1991 This volume contains 53 articles grouped under five headings 1 Research 14 papers on such topics as cognitive style and cognitive strategies visual literacy training and the impact of diagrams type styles and computer graphics on learning 2 Theory nine papers on such topics as the development of visual literacy concepts cognition and understanding visual intelligence instructional design and hypermedia 3 Computers and Technology six papers on such topics as hypermedia still photography high definition television and desktop publishing 4 Arts 12 papers on such topics as photography images and meaning incongruous imagery visual thinking and art and computer graphics and 5 Schools and Curriculum 12 articles on such topics as teaching visual literacy at the elementary high school and college levels illustration of children s books visual creativity visual design and schema construction Most papers contain references KRN

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