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

Supplemental materials: http://dx.doi.org/10.1037/1076-898X.14.1.36.supp

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).

Thinking Graphically Connecting Vision And Cognition

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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 **Engineering Psychology and Human Performance** Christopher D. Wickens,William S. Helton,Justin G. Hollands,Simon Banbury,2021-09-27 Forming connections between human performance and design this new edition of Engineering Psychology and Human Performance examines human machine interaction The book is organized directly from a psychological perspective of human information processing and chapters correspond to the flow of information as it is processed by a human being from the senses through the brain to action rather than from the perspective of system components or engineering design concepts Upon completing this book readers will be able to identify how human ability contributes to the design of technology understand the connections within human information processing and human performance challenge the way they think about technology s influence on human performance and show how theoretical advances have been or might be applied to improving human machine interactions This new edition includes the following key features A new chapter on research methods Sections on interruption management and distracted driving as cogent examples of applications of engineering psychology theory to societal problems A greatly increased number of references to pandemics technostress and misinformation New applications Amplified emphasis on readability and commonsense examples Updated and new references throughout the text This book is ideal for psychology and engineering students as well as practitioners in engineering psychology human performance and human factors The text is also supplemented by online resources for students and instructors **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 valuable resource for eye tracking researchers within the visualization community *Article Collection on Human Aspects in Adaptive and Personalized Interactive Environments (HAAPIE)* Vania Gatseva Dimitrova,Panagiotis Germanakos,Styliani Kleanthous,2021-01-11 **Morphogenesis and the Crisis of Normativity** Margaret S. Archer,2016-05-24 This volume explores the development and consequences of morphogenesis on normative regulation It starts out by describing the great normative transformations from morphostasis as the precondition of a harmonious relationship between legal validity and normative consensus in society to morphogenesis which tends to strongly undermine existing laws norms rules rights and obligations because of the new variety it introduces Next it studies the decline of normative consensus resulting from the changes in the social contexts that made previous forms of normativity based upon habits habitus and routine action unhelpfully misleading because they no longer constituted relevant guidelines to action It shows how this led to the Reflexive Imperative with subjects having to work out their own purposeful actions in relation to their objective social circumstances and their personal concerns if they were to be active rather than passive agents Finally the book analyses what makes for chance in normativity and what will underwrite future social regulation It discusses whether it is possible to establish a new corpus of laws norms and rules given that intense morphogenesis denies the durability of any new stable context Educational Measurement Linda L. Cook,Mary J. Pitoniak,2025 The fifth edition of Educational Measurement is a comprehensive handbook and textbook on the theories and techniques of the science of educational measurement It contains 22 chapters written by the leading scholars in educational measurement in the US Some chapters contain discussions of cutting edge research others document advancements in technology still others address issues related to the use of educational measurement to further the educational goals of a diverse and complex society *ACRN Proceedings in Finance and Risk Series '13* Dr. Othmar M. Lehner,Dr. Richard Harrison,2014-03-06 Proceedings of the 14th FRAP Finance Risk and Accounting Perspectives conference taking place in Cambridge UK *Seeing and Visualizing* Zenon W. Pylyshyn,2003 How we see and how we visualize why the scientific account differs from our experience *Current Index to Journals in Education* ,2000 **Industrial & Mining Standard** ,1915 *Proceedings, Information Visualization* Steve Eick,Nahum Gershon,1995 Contains the proceedings of the October 1995 symposium organized by session visualizing diagrams and functional designs four papers visualizing information spaces four papers and visualizing hierarchies and data bases three papers The final section offers seven case studies Includes 18 p **The Publishers' Trade List Annual** ,1995 Conference Proceedings ,2002 *Documentation Abstracts* ,1987 *Seeing,*

Thinking and Knowing A. Carsetti,2004-03-31 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   *Subject Guide to Books in Print* ,2001   **Resources in Education** ,1997   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   **Forthcoming Books** Rose Arny,2003

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