Diagrammatic Cognition: Discovery and Design

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Introduction

External representations of thought—maps, diagrams, sketches, and the like—are ancient inventions that serve thought and communication in numerous ways. A number of cognitive scientists have investigated roles these representations play in cognition (see, e.g., Donald, 1991; Larkin & Simon, 1987; Norman, 1993; Schön, 1983). They are created and used by school students, by architects and designers, by mathematicians and scientists, by musicians, dancers, and artists. People design and use diagrams to spatialize thought and make it public, to work through ideas and clarify thinking, to reduce working memory load, to communicate ideas to others, to promote collaborative work by providing an external representation that can be pointed to and animated by gestures and collectively revised. Considerable research has shown that well-designed diagrams promote thought, creativity, discovery, and communication. Diagrams can map abstract thought to space, allowing spatial reasoning to promote abstract reasoning.

Just as many diverse groups create and use diagrams, many diverse groups are actively studying their creation and use. Educators study ways to design effective diagrams and ways to educate students to use them. Psychologists study how diagrams are perceived, comprehended, and created. Both educators and psychologists study ways to promote the spatial thinking skills underlying comprehension and creation of diagrams. Designers study their use in design, artists their use in art. Historians and philosophers of science describe case studies of the insightful development of diagrams by scientists and the insights those diagrams have provided to others. Philosophers analyze formal properties of diagrams. Mathematicians explore the diagrammatic thinking that underlies mathematical thought and discovery. Computer scientists study ways computers can understand and process diagrams. Other computer scientists develop displays that will effectively analyze and convey Big Data. Journalism schools now teach data visualization and diagram narratives, as these are increasingly important in journalism. The proliferation of digital tools have proliferated the use of diagrams.

Goals and Plan of the Workshop

The goal of the workshop is dual: a) to bring together a diverse set of researchers working on various aspects of diagrammatic reasoning; b) to bring the issues and research to a broader audience in Cognitive Science. To these ends, the workshop will have presentations from many disciplines: psychology, philosophy, computer science, education, design, and more. There will be two kinds of presentations: i) overview papers (30 minutes) by established researchers and ii) blitz talks (5 minutes) presenting specific current research projects. Blitz presentations have been highly successful in previous workshops, and are standard and excellent at large computer science meetings. The blitz presentations will allow broad participation from the cognitive science community and stimulate discussion around specific findings.

Morning Session: Creating and Coordinating Diagrams

Barbara Tversky, "Creating Diagrams"
Professor Emerita of Psychology at Stanford University and a Professor of Psychology and Education at Teachers College, Columbia University, USA

Patrick Healey, "Coordinating Graphical Languages"
Professor for Human Interaction, School of Electronic Engineering and Computer Science, Queen Mary University of London, UK

David Kirsh, "Thinking with Illustrations"
Professor of Cognitive Science, University of California, San Diego, USA

Blitz Talks: Peter Coppin, University of Toronto; James Corter, Teachers College, Columbia University; Valeria Giardino, Free University Berlin; Azadeh Jamalian, Teachers College, Columbia University; Maithilee Kunda, Georgia Institute of Technology; David Peebles, University of Huddensfield; Anne Schüler, Knowledge Media Research Center; and others

Afternoon Session: Diagrams in Science

William Bechtel, "Ways Scientists Reason with Diagrams"
Professor of Philosophy, University of California, San Diego, USA

Peter Cheng, "Re-discovering diagrams and re-codifying knowledge in science"
Professor of Cognitive Science, Department of Informatics, University of Sussex, UK

Mary Hegarty, "Cognition and Metacognition in Reasoning with Diagrams"
Professor of Psychology, University of California, Santa Barbara, USA

Blitz Talks: Trevor Barrett, Univ. of California—Santa Barbara; Daniel Burnston, Univ. of California—San Diego; Jeff Nickerson, Stevens Institute of Technology; Benjamin Sheredos, Univ. of California—San Diego; Andy Stull, Univ. of California—Santa Barbara; and others

Research Contributions of the Speakers

The presenters of the overview papers have each made distinctive contributions to cognitive science research on diagrams. The following are selective highlights.

Tversky (2005, 2011) has emphasized how people design diagrams by abstracting and schematizing contents, taking advantage of their spatial properties. She emphasizes how diagrams overcome limitations of internal information processing capacities, organize thought, and promote inference and discovery. Turning the focus to the inter-individual coordination in the production and comprehension of visuospatial representations Healey (Healey, Swoboda, Umata, & King, 2007) investigates the parallels between talking and drawing as modes of communication and the factors affecting the evolution of graphical dialects. Kirsh (2010) has identified a variety of ways external representations enhance cognitive power, including by providing a shareable object of thought, reducing the cognitive cost of inference, and coordinating thinking.

The afternoon session turns to uses of diagrams in relation to science. Bechtel has focused on how diagrams function to represent phenomena to be explained (Bechtel & Abrahamsen, 2012), guide the search for the parts and operations of mechanisms (Sheredos, Burnston, Abrahamsen, & Bechtel, in press) and direct the recomposition of mechanisms in computational models and synthetic organisms. Hegarty (2010, 2011) has employed experimental techniques to identify the cognitive abilities that underlie intelligent use of spatial representations and to address how spatial intelligence facilitates learning by students in the natural sciences. Cheng (2002, 2011) has explored how developing appropriate novel diagrammatic formats can enhance student learning about electric circuits and probability.

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