CAMBRIDGE

Cambridge University Press
0521807107 - The Cambridge Handbook of Visuospatial Thinking
Edited by Priti Shah and Akira Miyake
Frontmatter
More information

The Cambridge Handbook of Visuospatial Thinking

The ability to navigate across town, comprehend an animated display of the functioning of the human heart, view complex multivariate data on a company's website, or read an architectural blueprint and form a three-dimensional mental picture of a house are all tasks involving visuospatial thinking. The field of visuospatial thinking is a relatively diverse interdisciplinary research enterprise. An understanding of visuospatial thinking, and in particular, how people represent and process visual and spatial information, is relevant not only to cognitive psychology but also to education, geography, architecture, medicine, design, computer science/artificial intelligence, semiotics, and animal cognition. The goal of this book is to present a broad overview of research on visuospatial thinking that can be used by researchers as well as students interested in this topic in both basic research and applied/naturalistic contexts.

Priti Shah is Assistant Professor in the Department of Psychology at the University of Michigan, Ann Arbor. She has published in the areas of spatial thinking, graphical display comprehension, and working memory, in such journals as the *Journal of Experimental Psychology: General*, the *Journal of Experimental Psychology: Applied*, the *Journal of Educational Psychology*, and *Science Education*.

Akira Miyake is Associate Professor in the Department of Psychology at the University of Colorado, Boulder. He is a Fellow of both American Psychological Association (Division 3: Experimental Psychology) and American Psychological Society. He has published in the areas of working memory, executive functions, language comprehension, and spatial thinking in such journals as *Cognitive Psychology* and the *Journal of Memory and Language*, and has been serving as Associate Editor for the *Journal of Experimental Psychology: General*.

Akira Miyake and Priti Shah are co-editors of another Cambridge University Press book (published in 1999), *Models of Working Memory: Mechanisms of Active Maintenance and Executive Control*.

© Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
0521807107 - The Cambridge Handbook of Visuospatial Thinking
Edited by Priti Shah and Akira Miyake
Frontmatter
More information

The Cambridge Handbook of Visuospatial Thinking

Edited by
PRITI SHAH & AKIRA MIYAKE

CAMBRIDGE
UNIVERSITY PRESS

© Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
0521807107 - The Cambridge Handbook of Visuospatial Thinking
Edited by Priti Shah and Akira Miyake
Frontmatter
More information

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo

Cambridge University Press
40 West 20th Street, New York, NY 10011-4211, USA

www.cambridge.org
Information on this title: www.cambridge.org/9780521807104

© Cambridge University Press 2005

This book is in copyright. Subject to statutory exception
and to the provisions of relevant collective licensing agreements,
no reproduction of any part may take place without
the written permission of Cambridge University Press.

First published 2005

Printed in the United States of America

A catalog record for this publication is available from the British Library.

Library of Congress Cataloging in Publication Data

The Cambridge handbook of visuospatial thinking / edited by
Priti Shah, Akira Miyake.
p. cm.
Includes bibliographical references and indexes.
ISBN 0-521-80710-7 (hardback) – ISBN 0-521-00173-0 (pbk.)
1. Mental representation. 2. Space perception. 3. Imagery
(Psychology) 4. Visualization. 5. Thought and thinking.
I. Shah, Priti, 1968– II. Miyake, Akira, 1966– III. Title.
BF316.6.C36 2005
152.14′2 – dc22 2004020365

ISBN-13 978-0-521-80710-4 hardback
ISBN-10 0-521-80710-7 hardback

ISBN-13 978-0-521-00173-1 paperback
ISBN-10 0-521-00173-0 paperback

Cambridge University Press has no responsibility for
the persistence or accuracy of URLs for external or
third-party Internet Web sites referred to in this book
and does not guarantee that any content on such
Web sites is, or will remain, accurate or appropriate.

© Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
0521807107 - The Cambridge Handbook of Visuospatial Thinking
Edited by Priti Shah and Akira Miyake
Frontmatter
More information

Contents

© Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
0521807107 - The Cambridge Handbook of Visuospatial Thinking
Edited by Priti Shah and Akira Miyake
Frontmatter
More information

© Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
0521807107 - The Cambridge Handbook of Visuospatial Thinking
Edited by Priti Shah and Akira Miyake
Frontmatter
More information

List of Contributors

Marcia L. Collaer
Department of Psychology
Middlebury College
Middlebury, VT 05753
collaer@middlebury.edu

Sergio Della Sala
Department of Psychology, PPLS
University of Edinburgh
Edinburgh EH89JZ
Scotland, United Kingdom
sergio@staffmail.ed.ac.uk

Eric G. Freedman
Department of Psychology
University of Michigan, Flint
Flint, MI 48502-1950
freedman@umich.edu

Diane F. Halpern
Berger Institute for Work, Family, and Children
Claremont McKenna College
850 Columbia Ave.
Claremont, CA 91711-6400
Diane.Halpern@claremontmckenna.edu

Mary Hegarty
Department of Psychology
University of California, Santa Barbara
Santa Barbara, CA 93106
hegarty@psych.ucsb.edu

Friderike Heuer
Department of Psychology
Lewis & Clark College
615 SW Palatine Hill Rd.
Portland, OR 97219-7899
heuer@lclark.edu

Amy E. Learmonth
Department of Psychology
Rutgers University
152 Frelinghuysen Rd.
Piscataway, NJ 08854-8020
amyel@rci.rutgers.edu

Robert H. Logie
Department of Psychology, PPLS
University of Edinburgh
Edinburgh EH89JZ
Scotland, United Kingdom
rlogie@staffmail.ed.ac.uk

© Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
0521807107 - The Cambridge Handbook of Visuospatial Thinking
Edited by Priti Shah and Akira Miyake
Frontmatter
More information

Richard E. Mayer
Department of Psychology
University of California, Santa Barbara
Santa Barbara, CA 93106
mayer@psych.ucsb.edu

Akira Miyake
Department of Psychology
University of Colorado at Boulder
345 UCB
Boulder, CO 80309-0345
akira.miyake@colorado.edu

Daniel R. Montello
Department of Geography
University of California, Santa Barbara
Santa Barbara, CA 93106
montello@geog.ucsb.edu

Nora S. Newcombe
Department of Psychology
Temple University
Philadelphia, PA 19122
newcombe@astro.ocis.temple.edu

Daniel Reisberg
Department of Psychology
Reed College
3203 SE Woodstock Blvd.
Portland, OR 97202
Daniel.Reisberg@directory.reed.edu

Mike Rinck
Maastricht University
Department of Medical, Clinical, and Experimental Psychology
Postbus 616
6200 MD Maastricht, NL
M.Rinck@DMKEP.unimaas.nl

Priti Shah
Department of Psychology
525 East University
University of Michigan
Ann Arbor, MI 48109–1109
priti@umich.edu

Holly A. Taylor
Department of Psychology
Paige Hall
Tufts University
Medford, MA 02155
htaylor@ tufts.edu

Barbara Tversky
Department of Psychology
Building 420
Jordan Hall
Stanford, CA 94305-2130
bt@psych.stanford.edu

Ioanna Vekiri
N. Plastira 103
Thessaloniki, 55132, Greece
aretsou@hol.gr

Michelle Vincow
Verizon Laboratories
18 Day St. #207
Somerville, MA 02144
mvincow@yahoo.com

David A. Waller
Department of Psychology
234 Benton Hall
Miami University
Oxford, OH 45056
wallerda@muohio.edu

© Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
0521807107 - The Cambridge Handbook of Visuospatial Thinking
Edited by Priti Shah and Akira Miyake
Frontmatter
More information

Christopher D. Wickens
Beckman Institute
University of Illinois
405 N. Mathews
Urbana, IL 61801
cwickens@uiuc.edu

Michelle Yeh
Volpe National Transportation
Systems Center
55 Broadway
Cambridge, MA 02142
yeh@volpe.dot.gov

© Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
0521807107 - The Cambridge Handbook of Visuospatial Thinking
Edited by Priti Shah and Akira Miyake
Frontmatter
More information

Preface

Navigating across town, comprehending an animated display of the functioning of the human heart, viewing complex multivariate data on a business's website, reading an architectural blueprint, and forming a three-dimensional mental picture of a house are all tasks involving visuospatial thinking. As suggested by the breadth of this list of tasks, the field of visuospatial thinking is a relatively diverse interdisciplinary research enterprise. An understanding of visuospatial thinking – in particular, how people represent and process visual and spatial information – is relevant not only to the field of cognitive psychology but also to education, geography, architecture, medicine, design, computer science/artificial intelligence, semiotics, and animal cognition.

The goal of this handbook is to present a broad overview of the research on this topic that can be used by researchers interested in visuospatial thinking in both basic and applied or naturalistic contexts. The focus of this volume is higher-level visuospatial thinking, which involves the use of internal or external visual or spatial representations from visual imagery to diagrammatic reasoning. Our focus on higher-level visuospatial thinking contrasts with lower-level visuospatial cognition, such as object recognition, visual attention, and scene perception.

There are at least three reasons why we felt that there is a need for this handbook. First, historically, research on visuospatial thinking has been a relatively loosely connected enterprise, often with little interaction among researchers addressing related questions. For example, although there are similar issues involved in the processing of graphs, diagrams, and maps, little communication across these research areas exists, and few generic models or theories can provide a unified framework for the comprehension of various visual displays. Similarly, although research on visuospatial

© Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
0521807107 - The Cambridge Handbook of Visuospatial Thinking
Edited by Priti Shah and Akira Miyake
Frontmatter
More information

thinking at multiple levels (e.g., object recognition, scene perception, diagram comprehension) has been done, few models cut across these levels. This state of affairs in the visuospatial thinking domain is in stark contrast to the field of text comprehension, where a number of well-developed models that cut across different levels of analysis already exist. By bringing together different lines of related research in a single volume, we believe that this handbook will provide one step toward the development of a more unified subdiscipline of cognitive science, the field of higher-level visuospatial thinking.

Another closely related reason is that much research on visuospatial thinking is distributed across different disciplines and in many cases has been conducted in the context of applied problems. For example, cognitive psychologists examine the nature of limitations in visuospatial working memory and specify the nature of individual and group differences in visuospatial abilities in lab-based settings (e.g., Logie & Della Sala, Chapter 3; Hegarty & Waller, Chapter 4; Halpern & Collaer, Chapter 5). At the same time, similar questions are asked in more applied contexts. Medical researchers consider how limitations in spatial abilities may affect surgeons using virtual tools, and meteorologists consider how spatial abilities may influence the interpretation of interactive weather displays. In another example, the communication of three-dimensional information in two-dimensional format is critical for many situations (e.g., Wickens, Vincow, & Yeh, Chapter 10; Shah, Freedman, & Vekiri, Chapter 11; and Mayer, Chapter 12), but extensive research related to this topic has been conducted in rather disparate fields, including chemistry, architecture, multimedia instruction, and radiology. Because of the distributed nature of research on visuospatial thinking across different domains, it has been difficult for researchers to know what relevant work has been done on a certain topic and to keep up with the large body of available research. A researcher in an applied domain (e.g., someone interested in three-dimensional visuospatial thinking during surgery) may not be prepared to identify the different communities that have examined related questions. Our intention is to bring together the important research on visuospatial thinking in different contexts so that researchers in various disciplines can apply what has been learned in other subfields of visuospatial thinking to their own fields.

A third reason for editing a handbook on visuospatial thinking is that current technology requires new types of visuospatial thinking. Information technology, for example, requires people to comprehend and use animated, three-dimensional, and interactive displays and also to navigate through virtual as well as physical space. Along with such technological

© Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
0521807107 - The Cambridge Handbook of Visuospatial Thinking
Edited by Priti Shah and Akira Miyake
Frontmatter
More information

advances are numerous new empirical studies – yet again, these studies are frequently done within the context of specific fields without making much contact with related research in other disciplines. In this handbook, several examples of visuospatial thinking involving current technology from navigation through virtual space to the comprehension of complex multimedia representations are presented and discussed in some detail.

We decided against including a larger number of short chapters, as is frequently done in books with the word *handbook* in the title. We instead opted for providing in-depth reviews of central topics in higher-level visuospatial thinking so that readers may gain a strong foundation in each selected topic. This means that the information contained here does not cover all possible topics within research on visuospatial thinking, but many of the core topics are covered in a fairly comprehensive manner in each chapter. From our own experience, we have found handbooks that are somewhat selective but offer an in-depth coverage of major topics more useful than those that offer a comprehensive yet somewhat cursory treatment of many topics, and we hope that readers also see some benefits in our "selective, in-depth" approach.

The handbook can be loosely divided into four sections, beginning with a section with the basic cognitive mechanisms underlying visuospatial thought, such as visuospatial imagery and working memory. In Chapter 1, Barbara Tversky begins with a fundamental theoretical issue that applies to all the remaining chapters in the volume, the role of visuospatial representations in human thought. Specifically, in her tutorial overview chapter, she addresses such fundamental questions as, "What kinds of internal and external visuospatial representations do we use, how do they relate to one another, and for what are they useful?" In Chapter 2, Dan Reisberg and Friderike Heuer provide an up-to-date review of research on mental imagery. Their chapter also includes the latest research on the neural basis of mental imagery, including sections on neuroimaging studies and research on neuropsychological patients with mental imagery deficits. In Chapter 3, Robert Logie and Sergio Della Sala provide an in-depth discussion of one important building block of visuospatial thinking – visuospatial working memory – from the perspective of neuropsychological studies of disorders of visuospatial cognition, particularly those of hemispatial neglect.

The second section of the handbook focuses on individual and group differences in spatial abilities. We devote a few chapters to this topic because historically this topic has been a relatively large component of cognitive research on visuospatial thinking and has been of practical importance to most applied topics in visuospatial thinking. In Chapter 4, Mary Hegarty

© Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
0521807107 - The Cambridge Handbook of Visuospatial Thinking
Edited by Priti Shah and Akira Miyake
Frontmatter
More information

and David Waller review the research on individual differences in visuospatial thinking, including psychometric spatial abilities, navigational skill, mechanical reasoning abilities, and other visuospatial abilities. They also consider various relationships among spatial abilities (e.g., navigation skill and psychometric spatial skill), the relationship between spatial ability and other skills (e.g., mathematical ability and musical skills), and the effects of aging on visuospatial thinking. In Chapter 5, Diane Halpern and Marcia Collaer critically evaluate evidence for sex-related differences in visuospatial abilities in humans and other animals. In addition, they consider underlying explanations for sex-related differences, such as differences in brain laterality, hormones, and life experiences. Finally, in Chapter 6, Nora Newcombe and Amy Learmonth provide an in-depth, theoretically motivated account of the development of spatial skills. The authors' main focus is children's ability to represent and use knowledge about geographical space, such as their ability to remember spatial locations, imagine space from different perspectives, and navigate through space.

The third section of the handbook focuses on constructing and using visuospatial mental representations in the performance of complex everyday tasks, such as navigation, map reading, and the comprehension of verbal directions. In Chapter 7, Daniel Montello provides a comprehensive review of current views on the mechanisms and representations involved in human navigation. In Chapter 8, Holly Taylor discusses research on the comprehension and production of maps and other external representations of geographical space. Finally, Chapter 9, written by Mike Rinck, concerns the nature of processes and representations involved in the mental construction of spatial representations from verbal descriptions (e.g., reading a passage in which the main character moves from one location to another). Called *spatial situation models*, these representations serve as an interface between visuospatial thinking and language comprehension.

The final section of the handbook presents four exemplar applied contexts that have lately received a large amount of research attention. In Chapter 10, Chris Wickens, Michelle Vincow, and Michelle Yeh discuss two of these contexts: navigational displays (e.g., pilot navigation or head mounted displays) and information visualization displays. In their chapter, the authors emphasize the importance of various frames of reference and the difficulties of translating between frames of reference in the context of different tasks. In Chapter 11, Priti Shah, Eric Freedman, and Ioanna Vekiri describe research on the comprehension of graphs. They consider the display, content, task, and individual difference factors that influence the interpretation of quantitative data presented visually. Finally, in Chapter 12,

© Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
0521807107 - The Cambridge Handbook of Visuospatial Thinking
Edited by Priti Shah and Akira Miyake
Frontmatter
More information

Richard Mayer examines the effects of visuospatial media on thinking and learning from an educational perspective and presents a model of multimedia comprehension and principles of multimedia.

As mentioned, this handbook is intended to serve as a resource for readers in the cognitive sciences as well as researchers in related disciplines who may have an applied interest in visuospatial cognition. In addition, we hope that this volume will be useful to advanced undergraduate and graduate students and other individuals who are interested in learning about the field of visuospatial thinking but do not have strong background knowledge in it.

To make this volume accessible to a broad, interdisciplinary audience as well as to novice student readers, we have implemented a number of features.

We asked chapter authors to define the technical terms that they used in their chapters, even when those terms were used in other chapters, so that each chapter can serve as an independent resource for the reader. Also, because handbook readers usually read a subset of chapters relevant to their interests rather than reading the entire book from cover to cover, we have deliberately maintained some level of redundancy across chapters so that readers would not have to refer to other chapters to comprehend the one they are reading. At the same time, we have included a number of cross-references in each chapter so that interested readers can learn more about the related topics by taking a look at other related chapters. Additionally, we solicited reviews of chapter drafts from graduate students. We explicitly asked these reviewers to identify any concepts or technical terms that were unclear to the reader and then asked the authors to revise their chapters accordingly. Each chapter was reviewed by experts in certain aspects of visuospatial thinking research so that the contents of each chapter are accurate and of interest to expert researchers in the field as well. Finally, we asked authors to provide a list of important further readings so that readers can use these chapters as a springboard for learning about different subfields of visuospatial thinking.

The field of visuospatial thinking is a diverse interdisciplinary research community. We hope that this handbook serves as a useful resource for researchers currently conducting research in visuospatial thinking as well as researchers new to the field and that it also provides a useful bridge between basic and applied research on visuospatial thinking.

Priti Shah and Akira Miyake

© Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
0521807107 - The Cambridge Handbook of Visuospatial Thinking
Edited by Priti Shah and Akira Miyake
Frontmatter
More information

Acknowledgments

We would like to thank a number of people and agencies that have supported this book project.

First, we would like to acknowledge granting agencies that have supported our own work during the time we have been working on this book. Priti Shah was supported by grants from the Office of Naval Research (N00014-98-1-0812, N00014-98-1-0350, and N00014-02-1-0279). Akira Miyake was supported by grants from the National Institute of Mental Health (MH63207).

We owe a debt of gratitude to the two groups of reviewers who provided detailed feedback on the chapters contained in this handbook. One group of reviewers consisted of experts on certain aspects of visuospatial thinking. The other group of reviewers were graduate students. For each chapter, two graduate students, one from within the discipline of cognitive psychology and one from outside of cognitive psychology but in a field relevant to visuospatial cognition (e.g., education, information science), reviewed the chapters for readability, comprehensibility, and content. These reviewers were (in alphabetical order): Damian Betebenner, Kirsten Butcher, Leslie Cohen, David Collister, Elizabeth Davis, Patricia DeLucia, Mike Emerson, Naomi Friedman, Julie Heiser, Jeff Holmes, Alex Kauper, Steve Kosslyn, Kate Masarik, Joe Mikels, Beth Mulligan, Mitch Nathan, Naomi Norman, Danny Oppenheimer, David Pearson, Jim Pellegrino, John Reiser, Patricia Reuter-Lorenz, Matt Rossano, Gunnar Schrah, Julia Sluzenski, Jim Van Overschelde, Sashank Varma, Daniel Voyer, and Rolf Zwaan. Thanks to all.

We would also like to thank people who generously helped us at various stages of the book project, including Linda Anderson, Aysecan Boduroglu, Evelyn Craft-Robinson, and Rachel Orlowski at the University of Michigan

© Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
0521807107 - The Cambridge Handbook of Visuospatial Thinking
Edited by Priti Shah and Akira Miyake
Frontmatter
More information

and Michie Shaw and Andrew Wilson at TechBooks. We would particularly like to thank our editor at Cambridge University Press, Phil Laughlin, for his thorough and timely help and especially his patience.

In addition, Priti Shah gratefully acknowledges the support of her colleagues and students at the University of Michigan on this book project as well as on her research. Jim Hoeffner has provided much love and support during the entire editing process. He deserves a mountain of thanks (and a vacation) (or two). Finally, Kiran and Avani provided lots of joyful diversions.

Akira Miyake gratefully acknowledges the support of his colleagues at the University of Colorado, Boulder, where most of the editing of this handbook (as well as our previous book with Cambridge University Press, *Models of Working Memory: Mechanisms of Active Maintenance and Executive Control*) took place. He is extremely grateful for the encouragement that his Boulder colleagues, students, and friends provided on these book projects as well as his research. He would also like to thank the University of Toronto for providing necessary resources for completing the last stages of the handbook editing process.

© Cambridge University Press www.cambridge.org