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The Cambridge Handbook of Multimedia Learning

Second Edition

Multimedia learning is learning from words and pictures. The rationale for studying multimedia learning is that people can learn more deeply from words and pictures than from words alone. Multimedia environments, including online presentations, e-courses, interactive lessons, simulation games, slideshows, and even textbooks, play a crucial role in education. *The Cambridge Handbook of Multimedia Learning* is unique in offering a comprehensive, up-to-date analysis of research and theory in the field, with a focus on computer-based learning. Since the first edition appeared in 2005, it has shaped the field and become the primary reference work for multimedia learning. In recent years, multimedia learning has developed into a coherent discipline with a significant research base, which is reflected in the 34 chapters of this handbook. This second edition incorporates the latest developments in multimedia learning, including a sharp increase in the research base, the addition of seven new principles of multimedia learning, a broadening of contexts for studying multimedia learning, a better delineation of boundary conditions for principles, and refinements of theories of multimedia learning.

RICHARD E. MAYER is Professor of Psychology at the University of California, Santa Barbara. He served as President of the Division of Educational Psychology of the American Psychological Association (APA) and as Vice President of the American Educational Research Association (AERA) for the Learning and Instruction Division. He received the E. L. Thorndike Award for career achievement in educational psychology, the Sylvia Scribner Award for research contributions in learning and instruction, and the Distinguished Contributions of Applications of Psychology to Education and Training Award from the American Psychological Association. He has authored more than 400 publications, including 25 books, such as *Applying the Science of Learning*, *Multimedia Learning*, *Learning and Instruction*, and *e-Learning and the Science of Instruction* (with R. Clark).

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978-1-107-03520-1 - The Cambridge Handbook of Multimedia Learning: Second Edition
Edited by Richard E. Mayer
Frontmatter
More information

Contents

List of Contributors *page* ix
Preface xi
Acknowledgments xvii

1. Introduction to Multimedia Learning 1
RICHARD E. MAYER

Part I. Theoretical Foundations

2. Implications of Cognitive Load Theory for Multimedia Learning 27
FRED PAAS AND JOHN SWELLER

3. Cognitive Theory of Multimedia Learning 43
RICHARD E. MAYER

4. Integrated Model of Text and Picture Comprehension 72
WOLFGANG SCHNOTZ

5. The Four-Component Instructional Design Model: Multimedia Principles in Environments for Complex Learning 104
JEROEN J. G. VAN MERRIËNBOER AND LIESBETH KESTER

Part II. Basic Principles of Multimedia Learning

6. Ten Common but Questionable Principles of Multimedia Learning 151
RICHARD E. CLARK AND DAVID F. FELDON

7. The Multimedia Principle 174
KIRSTEN R. BUTCHER

8. The Split-Attention Principle in Multimedia Learning 206
PAUL AYRES AND JOHN SWELLER

9. The Modality Principle in Multimedia Learning 227
RENAE LOW AND JOHN SWELLER

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CAMBRIDGE

Cambridge University Press
978-1-107-03520-1 - The Cambridge Handbook of Multimedia Learning: Second Edition
Edited by Richard E. Mayer
Frontmatter
More information

10. The Redundancy Principle in Multimedia Learning 247
SLAVA KALYUGA AND JOHN SWELLER

11. The Signaling (or Cueing) Principle in Multimedia Learning 263
TAMARA VAN GOG

12. Principles for Reducing Extraneous Processing in Multimedia Learning: Coherence, Signaling, Redundancy, Spatial Contiguity, and Temporal Contiguity Principles 279
RICHARD E. MAYER AND LOGAN FIORELLA

13. Principles for Managing Essential Processing in Multimedia Learning: Segmenting, Pre-training, and Modality Principles 316
RICHARD E. MAYER AND CELESTE PILEGARD

14. Principles Based on Social Cues in Multimedia Learning: Personalization, Voice, Image, and Embodiment Principles 345
RICHARD E. MAYER

Part III. Advanced Principles of Multimedia Learning

15. The Guided Discovery Learning Principle in Multimedia Learning 371
TON DE JONG AND ARD W. LAZONDER

16. The Worked Examples Principle in Multimedia Learning 391
ALEXANDER RENKL

17. The Self-Explanation Principle in Multimedia Learning 413
RUTH WYLIE AND MICHELENE T. H. CHI

18. The Generative Drawing Principle in Multimedia Learning 433
DETLEV LEUTNER AND ANNETT SCHMECK

19. The Feedback Principle in Multimedia Learning 449
CHERYL I. JOHNSON AND HEATHER A. PRIEST

20. The Multiple Representation Principle in Multimedia Learning 464
SHAARON AINSWORTH

21. The Learner Control Principle in Multimedia Learning 487
KATHARINA SCHEITER

22. Animation Principles in Multimedia Learning 513
RICHARD K. LOWE AND WOLFGANG SCHNOTZ

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CAMBRIDGE

Cambridge University Press
978-1-107-03520-1 - The Cambridge Handbook of Multimedia Learning: Second Edition
Edited by Richard E. Mayer
Frontmatter
More information

23. The Collaboration Principle in Multimedia Learning 547
PAUL A. KIRSCHNER, FEMKE KIRSCHNER, AND JEROEN JANSSEN

24. The Expertise Reversal Principle in Multimedia Learning 576
SLAVA KALYUGA

25. The Individual Differences in Working Memory Capacity Principle in Multimedia Learning 598
JENNIFER WILEY, CHRISTOPHER A. SANCHEZ, AND ALLISON J. JAEGER

Part IV. Multimedia Learning of Cognitive Processes

26. Multimedia Learning of Cognitive Processes 623
SUSANNE P. LAJOIE

27. Multimedia Learning of Metacognitive Strategies 647
ROGER AZEVEDO

28. Multimedia Learning and the Development of Mental Models 673
MARY HEGARTY

Part V. Multimedia Learning in Advanced Computer-Based Contexts

29. Multimedia Learning with Intelligent Tutoring Systems 705
BENJAMIN D. NYE, ARTHUR C. GRAESSER, AND XIANGEN HU

30. Multimedia Learning with Simulations and Microworlds 729
JAN L. PLASS AND RUTH N. SCHWARTZ

31. Multimedia Learning with Computer Games 762
SIGMUND TOBIAS, J. D. FLETCHER, BENOIT BEDIOU, ALEXANDER P. WIND, AND FEI CHEN

32. Multimedia Learning with Video 785
SHARON J. DERRY, MIRIAM GAMORAN SHERIN, AND BRUCE L. SHERIN

33. Multimedia Learning from Multiple Documents 813
JEAN-FRANÇOIS ROUET AND ANNE BRITT

34. Multimedia Learning in e-Courses 842
RUTH COLVIN CLARK

Author Index 883
Subject Index 905

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CAMBRIDGE

Cambridge University Press
978-1-107-03520-1 - The Cambridge Handbook of Multimedia Learning: Second Edition
Edited by Richard E. Mayer
Frontmatter
More information

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Edited by Richard E. Mayer
Frontmatter
More information

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Frontmatter
More information

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Edited by Richard E. Mayer
Frontmatter
More information

Preface

As the first and only comprehensive research-based handbook on multimedia learning, *The Cambridge Handbook of Multimedia Learning* has helped define and shape the field and has become recognized as its major reference work. Since the publication of the first edition in 2005, the field of multimedia learning has grown as a coherent discipline with an accumulated research base worthy of being synthesized and organized in an updated handbook. Therefore, I am pleased to serve as editor of this second edition of *The Cambridge Handbook of Multimedia Learning*, which remains the most comprehensive and up-to-date volume summarizing research and theory in the field of multimedia learning.

This second edition of the *Handbook* constitutes the latest progress report from the world's leading multimedia researchers. As in the first edition, the focus of this volume is on how people learn from words and pictures, particularly in computer-based environments. For purposes of the *Handbook*, multimedia learning is defined as learning from words (e.g., spoken or printed text) and pictures (e.g., illustrations, photos, maps, graphs, animation, or video). Multimedia environments include online instructional presentations, interactive lessons, e-courses, simulation games, slideshows, and even textbooks. Overall, the major goal of this second edition of the *Handbook* is the same as that of the first edition – to establish what works (by systematically examining research-based principles of effective multimedia instruction) and to explain how it works (by grounding the research findings in cognitive theory).

There are many books providing advice on how to design multimedia learning environments, but they are based largely on the practical experience and wisdom of the authors. Similarly, there are books reporting on the development of online instructional programs and Web sites, but the development efforts are generally based on best practices and informal case studies. Until recently, the lack of scientific research evidence in many multimedia learning books could be justified on the grounds that a solid research base did not yet exist. However, the quantity and quality of scientific research – conducted by researchers around the world – have reached a level warranting a revision of the field's first comprehensive research-based handbook of multimedia learning.

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Edited by Richard E. Mayer
Frontmatter
More information

What distinguishes this book from some other books on distance learning or Web-based instruction is our commitment to taking a scientific, evidence-based approach. My goal as editor is to make sure the *Handbook* provides a comprehensive and focused overview of the state of scientific research on multimedia learning. Each chapter is based on empirical research and grounded in cognitive theory, rather than offering unsubstantiated recommendations, describing best practices, or summarizing software development accomplishments. The chapter authors are research leaders from around the world, who have records of research publication in multimedia learning. As the most comprehensive research-based handbook on multimedia learning, the second edition of *The Cambridge Handbook of Multimedia Learning* is intended to continue to define and shape the field for years to come.

As the editor, I asked leading multimedia researchers to author chapters in areas in which they have contributed to the empirical research base. Because the field is largely international, the chapter authors span the globe, with more than half the chapters written by authors outside the United States – including chapter authors from Australia, Canada, Germany, France, the Netherlands, and the United Kingdom.

The *Handbook* consists of 34 chapters organized into five parts. Each chapter focuses on a particular theory of multimedia learning (in Part I), a basic principle of multimedia learning (Part II), an advanced principle of multimedia learning (Part III), multimedia learning of cognitive processing (Part IV), or multimedia learning within an advanced computer-based context (Part V).

In order to provide a common structure among the chapters, I asked authors to organize their chapters around a common set of issues. In particular, I asked the authors of the theory chapters in Part I to provide a concise description of the theory or model with concrete examples, to summarize the theory's contributions to cognitive theory (i.e., to specify predictions that have been tested), to summarize the theory's contributions to instructional design (i.e., to specify recommendations for instruction), to describe any limitations of the theory, and to suggest future directions for research. I asked the authors of each of the other chapters to provide a clear definition and example of the principle or topic of the chapter, to review the relevant published research literature in sufficient detail, to assess the limitations of the research base, to summarize the implications for cognitive theory and for instructional design, and to suggest directions for future research.

I solicited chapters that were concise (i.e., containing no more than 40 double-spaced pages), focused (i.e., reviewing the research on the specified topic), well-referenced (i.e., containing a rich set of relevant references), evidence-based (i.e., providing an up-to-date review of the best empirical evidence), theory-based (i.e., relating the findings to testable predictions of theories when appropriate), and educationally relevant (i.e., drawing

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Frontmatter
More information

implications for educational practice when appropriate). In order to minimize confusion, I asked the authors to clearly define jargon terms in the text as well as in a glossary at the end of the chapter. Each chapter was reviewed and revised.

This book is for anyone interested in how people learn from words and pictures in computer-based environments. Although the *Handbook* summarizes the research base in multimedia learning, it is intended to be accessible to a general audience. On one hand, the *Handbook* is designed to support readers with practical interests in how to design or select multimedia learning environments that promote learning. On the other hand, it is designed to support readers who have academic interests in conducting or evaluating research in multimedia learning. The *Handbook* would be appropriate for courses related to cognitive science, educational psychology, instructional design, human factors, multimedia arts and technology, professional training, and interface design. It would also be useful for instructors interested in designing or improving multimedia lessons in school settings, job training contexts, and informal environments. In short, *The Cambridge Handbook of Multimedia Learning* belongs on the bookshelf of anyone who is interested in taking an evidence-based approach to Web-based learning, e-learning, hypermedia, multimedia, computer games, Web site design, distance learning, instructional technology, human–computer interaction, virtual environments, or applied cognitive psychology.

As the editor, I have tried to ensure that the *Handbook* reflects the values that I think are important for our field. In particular, I sought to produce a handbook with the following characteristics:

Research-based: The *Handbook* is intended to summarize the empirical research on multimedia learning rather than describe untested best practices or software development projects. Although I have much respect for the craft knowledge of practitioners and designers, it is important to know if recommendations are supported by scientific evidence and under what conditions they are supported. Thus, I value a focus on scientific evidence as the key to progress in our field.

Theory-grounded: The *Handbook* is intended to relate empirical research to cognitive theories of how people learn. My overriding premise is that multimedia learning environments should be designed in ways that are consistent with what is known about how people learn.

Educationally relevant: The *Handbook* focuses on issues that are relevant to education, that is, to helping people learn. Thus, I sought chapters that offer research-based implications for instructional design.

Comprehensive: The *Handbook* offers a broad view of the field, including contributions from multimedia researchers around the world. I value the perspectives of researchers who have devoted so much of their energy to understanding multimedia learning.

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Edited by Richard E. Mayer
Frontmatter
More information

Timely: The *Handbook* offers an up-to-date overview of the field. I value timelines because the scientific study of multimedia learning is maturing at a rapid pace, and so are the practical demands for building multimedia learning environments – ranging from e-courses to in-class simulations.

Readable – In my role as editor I have tried to make sure that the chapters are clear and concise, with key terms defined and concrete examples provided. In a multidisciplinary field like this one, it is important that the chapters communicate what is known in a way that general readers can appreciate.

In short, my values motivated me to seek chapters based on empirical research and grounded in cognitive theory rather than chapters that mainly describe development efforts or best practices.

In order to prepare for the second edition, I solicited suggestions from 12 leading multimedia researchers concerning new chapters to add, old chapters to delete or reshape, and new authors to include. I also examined notes and comments I had received and made concerning the first edition, and I examined the current state of the field in terms of research activity. In light of this analysis, I sought to retain the *Handbook*'s basic goal and structure but to ask authors to update and revise their chapters.

This second edition of the *Handbook* begins (in Part I) with a look at four foundational theories of multimedia learning, each of which has been updated since the previous edition – Sweller's cognitive load theory, Mayer's cognitive theory of multimedia learning, Schnotz's integrated model of text and picture comprehension, and van Merriënboer's four-component instructional design theory.

As in the first edition, each core chapter (in Parts II and III) focuses on a well-established effect or principle that has been researched extensively. On the basis of developments in the field, I added a chapter on the signaling principle (i.e., highlighting parts of a graphic during instruction) to Part II. In Part III, I added chapters on the drawing principle (i.e., asking learners to draw during learning), feedback principle (i.e., giving explanations after learner responses), multiple representation principle (i.e., using different modes to present the information), animation principle (i.e., presenting graphics in dynamic form), learner control principle (i.e., allowing the learner to make choices about the pace and order of instruction), and working memory principle (i.e., the role of individual differences in working memory). I deleted chapters on aging, site maps, and navigation and incorporated much of the material into other chapters to better reflect the development of the research base during the past decade.

In ensuing chapters (in Parts IV and V), I asked the authors to examine the research base in specific contexts of multimedia learning such as teaching of metacognitive skills in a hypertext environment or teaching of cognitive skills using educational games. I reshaped Part IV to focus on multimedia

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Edited by Richard E. Mayer
Frontmatter
More information

learning of specialized content – cognitive skills, metacognitive strategies, and reasoning about complex systems – which has grown rapidly in the past 10 years, and to downplay multimedia learning in subject areas – deleting chapters on reading, mathematics, history, chemistry, meteorology, and second-language learning, which are better covered in other chapters. In Part V, I broke the chapter on simulations and games into two separate chapters to better reflect the growth of both of those areas, I substituted a chapter on multimedia learning with intelligent tutoring systems for chapters on multimedia learning with pedagogical agents and in virtual reality to also better reflect current research directions, I substituted a chapter on multimedia learning from multiple sources for one on hypermedia, and I added a chapter on learning with video to reflect the development of a solid research base.

Editing this book has been a treat for me, because I could commission chapters from the best researchers in the field and be the first to learn what they had to say. I am pleased to share the fruits of this enterprise with you in a timely fashion. My hope is that you will enjoy reading this *Handbook* as much as I have enjoyed editing it. I will consider it a success if it helps you to understand what is known about how people learn from words and pictures, gives you useful help in building or selecting effective multimedia learning environments, or encourages you to produce or investigate research that contributes to cognitive theory and educational practice. I hope that you will feel free to contact me at mayer@psych.ucsb.edu to share your comments about the *Handbook*.

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More information

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Edited by Richard E. Mayer
Frontmatter
More information

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Although my name is listed as the editor, this *Handbook* depended on the contributions of many people. In particular, I wish to thank the chapter authors for producing excellent chapters, for keeping this project on schedule, and for responding so well to the reviewers' comments. In particular, I wish to thank John Sweller and Jeroen van Merriënboer, who, in addition to providing outstanding chapters, gave me invaluable feedback on my own chapters. I also wish to thank David Repetto, Matthew Bennett, Hetty Marx, and the staff of Cambridge University Press for their many contributions to making this book a success. I am grateful to my many research collaborators who have worked with me over the years in the study of multimedia learning, including Deanne Adams, Richard B. Anderson, Robert Atkinson, Julie Campbell, Paul Chandler, Dorothy Chun, Ruth Clark, Krista DeLeeuw, Gayle Dow, Logan Fiorella, Joan Gallini, Shannon Harp, Mary Hegarty, Julie Heiser, Nabil Issa, Cheryl Johnson, Lewis Johnson, Claudia Leopold, James Lester, Detlev Leutner, Steven Lonn, Patricia Mautone, Sarah Mayer, Bruce McLaren, Roxana Moreno, Harold O'Neil, Jr., Celeste Pilegard, Jan Plass, Hector Ponce, Annett Schwamborn, Valerie Sims, Hiller Spires, Andy Stull, Eunmo Sung, and Ning Wang. I appreciate my home institution – the University of California, Santa Barbara – and numerous funding agencies, including the National Science Foundation, the Office of Naval Research, the U.S. Department of Education, and the Andrew Mellon Foundation, which have supported my research on multimedia learning. Finally, my deepest appreciation goes to my wife, Beverly; my children, Ken, David, and Sarah; my grandchildren, Jacob, Avery, James, Emma, and Caleb; and to the memory of my parents, James and Bernis Mayer.

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