COGNITION, BRAIN, AND CONSCIOUSNESS

SECOND EDITION

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Introduction to Cognitive Neuroscience

Second Edition

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AMSTERDAM • BOSTON • HEIDELBERG • LONDON • NEW YORK • OXFORD
PARIS • SAN DIEGO • SAN FRANCISCO • SINGAPORE • SYDNEY • TOKYO
Academic Press is an imprint of Elsevier

Academic Press is an imprint of Elsevier
30 Corporate Drive, Suite 400, Burlington, MA 01803, USA
525 B Street, Suite 1900, San Diego, California 92101-4495, USA
Elsevier, The Boulevard, Langford Lane, Kidlington, Oxford, OX5 1GB, UK

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Library of Congress Cataloging-in-Publication Data

Baars, Bernard J.

Cognition, brain, and consciousness : introduction to cognitive neuroscience/Bernard Baars, Nicole Gage. — 2nd ed.

p. cm.

Includes bibliographical references and index.

ISBN 978-0-12-375070-9 (hardcover : alk. paper) 1. Cognitive neuroscience. I. Gage, Nicole M. II. Title.

QP360.5.B33 2010

612.8'233—dc22

2009039469

British Library Cataloguing-in-Publication Data

A catalogue record for this book is available from the British Library.

ISBN:978-0-12-375070-9

For color figures, glossary, and study guide, please visit our companion website: www.baars-gage.com

For information on all Academic Press publications visit our Web site at www.elsevierdirect.com

Printed in China

10 11 12 9 8 7 6 5 4 3 2 1

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Preface

Keeping up-to-date with cognitive neuroscience is much like surfing the Big Wave at Waikiki Beach. New findings keep rolling in and maintaining a stable balance is a big challenge. It is exciting, fun, and, at times, a little bit scary. But we keep climbing back on our mental surfboards, to catch the coming rollers of advancing science. This book aims to provide an overview of the emerging science of mind and brain in a way that is accessible to students and interested readers at all levels.

For the Second Edition a number of new features have been added.

1. A new chapter on the *Genes and Molecules of Cognition* (Chapter 16) introduces essential new developments in the molecular basis of cognition. Neurons build links with other neurons by expressing proteins, directed by the genetic (and epigenetic) apparatus of the cell. Thus the molecular level has become essential for understanding learning, language, perception, thinking, and other basic functions. This chapter presents 'genes and molecules' in readily understandable ways.
2. A complete revision of the chapter on *Consciousness and Attention* (Chapter 8) takes into account the last ten years of research. New recording methods have led to remarkable breakthroughs. For example, brain rhythms have been shown to carry both conscious and unconscious information. The Second Edition is fully up-to-date on these findings.
3. A major revision of Chapter 12, *Goals, Executive Control, and Action* has been included. The frontal lobes have been called 'the organ of civilization' but they have long been viewed as mysterious. Many of the traditional puzzles are now clearing up, as this chapter explains, with a presentation of the current view of the organizing principles of the prefrontal cortex.
4. Individual scientists are presented in text boxes called *Frontiers in Cognitive Neurosciences.* These leading scientists from around the globe present their views about new directions and important findings in their discipline within the broader field of Cognitive Neuroscience:
   - Nelson Cowan, PhD, University of Missouri
   - David Eagleman, PhD, Baylor College of Medicine
   - Gerald Edelman, MD, The Neurosciences Institute
   - Paul Fletcher, PhD, University of Cambridge
   - Angela Friederici, PhD, Max Planck Institute for Human Cognitive and Brain Science
   - Christopher Frith, PhD, Wellcome Trust Centre for Neuroimaging
   - Christof Koch, PhD, Division of Biology, California Institute of Technology
   - Stephen L. Macknik, PhD, Barrow Neurological Institute
   - Susana Martinez-Conde, PhD, Barrow Neurological Institute
   - Aniruddh Patel, PhD, The Neurosciences Institute
   - Charan Ranganath, PhD, University of California, Davis
   - Michael Rugg, PhD. University of California, Irvine
   - Jenny Saffran, PhD, University of Wisconsin, Madison
   - Larry Squire, MD, University of California, San Diego School of Medicine
5. A new Glossary of technical terms has been added. Since vocabulary is one of the great challenges in learning cognitive neuroscience, we expect the Glossary to be a basic tool for students and instructors.

6 A new Mini-Atlas of the Human Brain has been added in pullout form at the front of the book. Knowing one's way around the brain is the first step in understanding the mind-brain sciences. But the brain is simply enormous in complexity and topographical knottiness. In the First Edition we used illustrations from *Gray's Anatomy* and other Elsevier/Academic Press sources to create a lavishly illustrated text. The Second Edition adds a Mini-Atlas to give newcomers even more support to explore the landscape of the brain – a compass and map of the territory.

7 The Appendix on Brain Imaging Methods has been completely updated by an expert in that field, Dr. Thomas Ramsoy of the University of Copenhagen.

As Christopher Frith, Michael Posner, and others have written, we are seeing a marriage of the cognitive and brain sciences, building on historic advances over the past few decades. Cognitive and perceptual mechanisms that were inferred from behavior can now be observed more directly in the brain, using a variety of novel brain imaging methods. For the first time, we can observe the living brain in real time, doing what it has evolved to do over hundreds of millions of years. The result is astonishingly rich, combining psychology and biology, medicine, biochemistry, and physics. Yet most scientific studies use well-established psychological concepts and methods. As a result, we are now seeing how psychology and brain science complement each other in surprising and gratifying ways. The field of *cognitive neuroscience* is becoming a basic educational requirement in psychology, biology, education, and medicine.

Cognitive neuroscience has been difficult to cover in a single course. Many instructors discover that they spend most of the term explaining the brain, with little time left for integrative topics. While understanding the brain is vital, an exclusive focus on anatomy can defeat the instructors' objectives.

This text approaches that challenge in several ways. First, the body of the text follows the gentlest learning curve possible, running along familiar lines: sensory perception in vision and audition, working memory, attention and consciousness, memory, executive functions, language and imagery, problem solving, emotion, social cognition, and development. The brain is introduced step by step, with gradually increasing sophistication. To make sense of the material we use a *functional framework* throughout the book. This widely accepted set of ideas allows us to see our major topics in a single schematic diagram, which grows in depth and detail over the course of the book. The functional framework can be seen from different perspectives. For example, memory stores may be viewed from an active working memory perspective; or perception, cognition, and control may be seen as playing upon permanently stored information in the brain (Chapter 2). The framework helps either way.

A website for teachers and students is available at http://textbooks.elsevier.com via a free registration. Supportive materials for teachers include all figures and captions from the book in powerpoint format, as well as instructional video and multimedia files. Student materials include chapter reviews, quizzes, figures, and videos. The support site will be dynamic. Materials will be added and changed as warranted by new advances, and the authors are happy to consider additional ideas and suggestions for new supportive materials.

Instructors may present the chapters in any order that suits their goals. For advanced students, Chapters 4 and 5 on brain imaging and anatomy may be covered lightly. For introductory courses those chapters are essential and may be supplemented with the more challenging appendix (by Thomas Ramsøy and colleagues). The appendix can also be used as a convenient reference sources.

A full range of brain disorders are covered, from HM and the case of Clive Wearing (Chapters 2 and 9), to blindsight, visual neglect, face blindness and other visual deficits (Chapter 6). Chapter 11 on executive function covers disorders of undercontrol and overcontrol. In certain disorders, motor and cognitive control is not directly impaired at all; it seems as if patients are just not willing to act. At the other pole, patients sometimes spontaneously imitate another person's actions as if they cannot stop themselves. Such patients may stand up impulsively when the examining physician stands up. Disorders of overcontrol and undercontrol reveal basic aspects of human executive functioning.

Some disorders have close psychological analogs. Professional musicians, like pianist Van Cliburn, are sometimes unable to inhibit their tendency to sing along with instrumental playing. Highly trained experts can lose some executive control over automatic behaviors, especially if they are working under mental workload. On the opposite side, a classic symptom of severe depression is that patients seem unable to initiate and pursue actions. Brain regions involved in such 'purely psychological' deficits are often implicated in similar organic disorders. We see another striking

simplification of the evidence, giving readers a chance to understand unifying principles rather than scattered facts.

Psychological topics are often simplified by brain evidence. For example, the verbal part of classical working memory – the capacity mentally to rehearse numbers and words – is now thought to be a part of our normal language capacity. Baddeley (2003) has emphasized the discovery that silent rehearsal activates the well-known speech regions of cortex. Thus the 'phonological loop' of traditional working memory is no longer seen as a separate cognitive feature, but rather as a silent way of using speech cortex. Similarly, Kosslyn and others have shown that visual imagery makes use of a subset of the cortical areas involved in normal visual perception (2004). Even more surprising, visual attention appears to be closely related to eye movement control. Athletes and musicians use the sensorimotor brain to engage in silent mental practice. Thus 'inner' and 'outer' processes seem to involve overlapping regions of the brain, a major simplification of the evidence.

While cognitive neuroscience does not always simplify things, it does so often enough to allow us to organize this text along recurring themes. This makes the material easier to teach and understand. It allows us to explore a wide range of basic topics, including emotion, social cognition, and development.

The companion materials are designed to enrich student learning by way of vivid classroom demonstrations, images, and learning points, using Powerpoint presentations and movie clips. A number of phenomena in the text can be best illustrated by way of experiments and movie clips. For example, a patient is shown with locked-in syndrome, able to communicate only by means of eye movements directed at a keyboard display. For comparison, we show patients who look superficially the same, but who are suffering from true coma.

At the end of each chapter, review questions and brain drawing exercises are designed to help students learn interactively. We particularly emphasize drawing and coloring exercises as a way to grasp the knotty three-dimensional organization of the brain.

This text covers some frontier topics in the ever-changing vista of cognitive neuroscience. One popular topic is the relationship of 'the mind' as we experience it and 'the brain' as we observe it: i.e. the historic topic of consciousness and its brain correlates. Alan Baddeley recently noted that, 'Perhaps the greatest change over the last twenty years within cognitive psychology and cognitive science . . . has been the acceptance of consciousness as a legitimate and tractable scientific problem'.

The renewed acceptance of consciousness has changed research in perception, memory, and attention, as seen in pioneering work by Endel Tulving, Daniel Shachter, Gerald Edelman, Francis Crick, Christof Koch, and numerous others. While some textbooks have added chapters on consciousness, we believe that the topic has now become so pervasive that it needs to be addressed throughout. As *Science* journal recently noted in its 125th anniversary issue, consciousness is now thought to be one of the major unsolved problems in biological science. While much remains to be learned, psychologists have long studied conscious processes under such headings as 'explicit cognition' and 'focal attention'. Those constructs are all assessed by the behavioral index of accurate report, which has been taken to signal conscious events since the beginning of psychophysics, some two centuries ago. Thus 'consciousness' can be seen as an umbrella label, much like 'memory' and 'perception', with a number of subtopics like subliminal perception, autobiographical memory, and focal attention.

Voluntary control is also back on the forefront of research, sometimes under the rubric of 'strategic control' and 'executive functions'. In the brain, voluntary and non-voluntary functions can be clearly distinguished anatomically and physiologically. Robust differences also appear in functional brain imaging and behavior. Finally, the notion of executive control appears to be moving toward new insights on the 'self' of everyday life, as studied in social and personality psychology.

All these topics show a striking convergence of behavioral and brain evidence.

The brain basis of emotion and social relationships is developing as well. 'Mirror neurons' are involved with the ability to perceive intentions in others; unconscious 'threat faces' can stimulate the amygdala; and conflicting aspects of self-control are apparently played out in competing impulses in prefrontal cortex.

Cognitive neuroscience is challenging; it is also one of the most important frontiers in science. Students will be rewarded with a new depth of understanding of human nature, one that has never been quite as clear and convincing as it is today.

The editors are especially grateful to Dr. Johannes Menzel, Publisher, Science Solutions and Content Strategy, Elsevier Publishers. We are also very grateful to Clare Caruana, Development Editor, Life Science

Books, Academic Press, Elsevier, for her guidance and support throughout our efforts for this Second Edition. During the preparation for our Second Edition, Johannes and Clare moved on to new and greater challenges at Elsevier and we welcomed Mica Haley, Senior Acquisitions Editor, and Melissa Turner, Development Editor, to our team. Mica and Melissa picked up the Second Edition and seamlessly guided us through the complex stages of producing a large text. We are grateful for all of their efforts on our behalf. We appreciate their consistent kindness, advice, and support throughout a very challenging project. Indeed, the current text would have been impossible without the vast archival resources of Elsevier.

We are grateful for our many contributors who added their expertise to this volume:

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The first editor is particularly grateful to Dr. Gerald Edelman and his colleagues at the Neurosciences Institute in San Diego, as a unique source of insight and collegial guidance on many topics in neuroscience. He is also indebted to the Mind Science Foundation of San Antonio, Texas, for supporting pioneering explorations in the cognitive neuroscience of consciousness. MSF's Board and Executive Director, Joseph Dial, have been especially active in working to unify behavioral and brain approaches to conscious experience (www.mindscience.org).

A number of colleagues and friends have helped us to gain a deeper understanding of mind and brain. There are too many to list here, but we want them to know of our gratitude. Among recent colleagues, Stan Franklin, Walter Freeman, William P. Banks, E. R. John, Christof Koch, Francis Crick, Karl Pribram, Dan Dennett, Patricia Churchland, Patrick Wilken, Geraint Rees, Chris Frith, Stan Dehaene, Bjorn Merker, Jaak Panksepp, Stu Hameroff, Thomas Ramsøy, Antti Revonsuo, Michael Pare, Henry Montandon, Murray Shanahan, and many others have helped us to think through the issues. We have not always agreed, but we have always felt grateful for their constantly interesting and important ideas.

We have been fortunate to have the help of outstanding co-authors for this book. Their contributions are acknowledged in the Contents. This book would be poorer without their depth of knowledge and desire to communicate.

In a broader but very real sense, this book owes everything to the community of scholars and scientists who are cited in its pages.

In more personal terms, the first editor would like to acknowledge his loved ones for putting up with him during this daunting project. His parents, now deceased, are still a constant source of inspiration and

guidance. He would also like to express his gratitude to Dr. Barbara Colton for constant feedback and support, which have made the book much more readable and the editor far more sensible.

Ms. Blair Davis was invaluable in helping to put this book through its final stages. Mr. Shawn Fu provided a number of beautiful brain illustrations.

The second editor is particularly grateful to the first editor for sharing his concept and passion for this project. Our collaboration on this text began a few years ago during a 3-hour layover in Chicago and has blossomed into this full-blown project, along with a strong friendship. She is also indebted to many colleagues and friends with whom she has learned about how language gets wired up in the brain. There are too many to include here, but she is indebted to them all. She is particularly grateful to Greg Hickok, David Poeppel, Larry Cahill, Norm Weinberger, Bryna Siegal, Anne Spence, and Kourosh Saberi for good conversations, ongoing debates, and thoughtful discussions through the years.

The second editor would like to acknowledge her family for their constant support during this project. Last, she is indebted to Kim for his insight and love.

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