



ENCYCLOPEDIA OF

# THE HUMAN BRAIN

SECOND EDITION

EDITOR IN CHIEF

**JORDAN H. GRAFMAN**

VOLUME ONE



# **ENCYCLOPEDIA OF THE HUMAN BRAIN**

---

SECOND EDITION

This page intentionally left blank

# ENCYCLOPEDIA OF THE HUMAN BRAIN

---

## SECOND EDITION

EDITOR IN CHIEF

**Jordan Henry Grafman**

*Director, Brain Injury Research, Chief, Cognitive Neuroscience Lab.  
Think and Speak Lab, Shirley Ryan Ability Lab, Chicago, IL, United States  
Professor, Department of Physical Medicine & Rehabilitation, Neurology,  
Cognitive Neurology and Alzheimer's Center, Department of Psychiatry,  
Feinberg School of Medicine & Department of Psychology,  
Weinberg College of Arts and Sciences, Northwestern University, Chicago, IL, United States*

## VOLUME 1

SECTION EDITORS

**Stephanie Forkel**

*Donders Institute, Radboud University, and Max Planck Institute,  
Nijmegen, Netherlands*

**Hugo Critchley**

*Department of Psychiatry, Brighton and Sussex Medical School,  
Brighton and Hove, United Kingdom*

**Angela Sirigu**

*iMIND Center of Excellence for Autism, Vinatier Psychiatric Hospital, Lyon, France*

**Jean-Rene Duhamel**

*Institut des Sciences Cognitives Marc Jeannerod CNRS,  
Université Claude Bernard, Lyon, France*



ELSEVIER

AMSTERDAM • BOSTON • HEIDELBERG • LONDON • NEW YORK • OXFORD  
PARIS • SAN DIEGO • SAN FRANCISCO • SINGAPORE • SYDNEY • TOKYO

Elsevier  
Radarweg 29, PO Box 211, 1000 AE Amsterdam, Netherlands  
125 London Wall, London, EC2Y 5AS, United Kingdom  
50 Hampshire Street, 5th Floor, Cambridge MA 02139, United States

Copyright © 2025 Elsevier Inc. All rights are reserved, including those for text and data mining, AI training, and similar technologies.

Publisher's note: Elsevier takes a neutral position with respect to territorial disputes or jurisdictional claims in its published content, including in maps and institutional affiliations.

No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from the publisher. Details on how to seek permission, further information about the Publisher's permissions policies and our arrangements with organizations such as the Copyright Clearance Center and the Copyright Licensing Agency, can be found at our website: [www.elsevier.com/permissions](http://www.elsevier.com/permissions).

This book and the individual contributions contained in it are protected under copyright by the Publisher (other than as may be noted herein).

#### Notices

Knowledge and best practice in this field are constantly changing. As new research and experience broaden our understanding, changes in research methods, professional practices, or medical treatment may become necessary.

Practitioners and researchers may always rely on their own experience and knowledge in evaluating and using any information, methods, compounds, or experiments described herein. In using such information or methods they should be mindful of their own safety and the safety of others, including parties for whom they have a professional responsibility.

To the fullest extent of the law, neither the Publisher nor the authors, contributors, or editors, assume any liability for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions, or ideas contained in the material herein.

#### Library of Congress Cataloging-in-Publication Data

A catalog record for this book is available from the Library of Congress

#### British Library Cataloguing-in-Publication Data

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

ISBN 978-0-12-820480-1

For information on all publications visit our website at  
<http://store.elsevier.com>



*Publisher:* Oliver Walter  
*Acquisitions Editor:* Michael Nicholls  
*Content Project Manager:* Ramalakshmi Boobalan  
*Associate Content Project Manager:* Rajeswari R  
*Designer:* Matthew Limbert

# CONTENTS OF VOLUME 1

---

<i>Contributors to Volume 1</i>	<i>ix</i>
<i>Editor in Chief</i>	<i>xv</i>
<i>Section Editors</i>	<i>xvii</i>
<i>Preface</i>	<i>xxv</i>

## **Anatomy**

Navigating neuroanatomy <i>Lilit Dulyan, Eva Guzmán Chacón, and Stephanie J Forkel</i>	1
Brain cell types and distribution <i>Roxana N Kooijmans</i>	9
Cortical surface anatomy <i>Oi Yean Wong and Asthik Biswas</i>	24
Anatomy of the cerebellum <i>Thomas Visser, Maitreyee Kulkarni, Jerillyn S Kent, and Sheeba Anteraper</i>	44
Human brain vasculature <i>Jacopo Bellomo, Antonio Spinello, Alberto Morello, Tilman Schubert, Jorn Fierstra, Amedeo Piazza, and Carlo Serra</i>	62
Cranial nerves <i>Flavia Massey and Harith Akram</i>	88
Brainstem <i>Bogdana Suchorska and Paul Naser</i>	113
Brain parcellations <i>Anna Plachti, Somayeh Maleki Balajoo, and Sarah Genon</i>	132
Genetics of neuroanatomy <i>Bernardo de APC Maciel, Martijn van den Heuvel, and Rachel M Brouwer</i>	148
Brain asymmetries <i>Sebastian Ocklenburg</i>	156
Clinical neuroanatomy <i>Maximilian Schwendner, Sebastian Ille, and Sandro M Krieg</i>	169

**Autonomic Functions**

The extended autonomic system: An integrative physiological perspective <i>David S Goldstein and Eduardo E Benarroch</i>	178
Allostatic interoception and brain health: From neurodegeneration to social adversities <i>Joaquín Migeot and Agustín Ibáñez</i>	204
Emotion & the autonomic nervous system <i>Greg J Norman, Kelly E Faig, and Gary G Berntson</i>	222
Brainstem nuclei in autonomic control and arousal <i>Feliberto de la Cruz, Karl-Jürgen Bär, and Andy Schumann</i>	232
Computational modeling and autonomic control <i>Chatrin Suksasilp, Karl Friston, and Sarah Garfinkel</i>	245
Cortical and subcortical components involved in the sympathetic control of blood pressure in humans <i>Vaughan G Macefield and Luke A Henderson</i>	267
Central regulation of the heart <i>Joel Patchitt and Hugo Critchley</i>	272
Neurophysiological substrates of cardiovascular reactivity to stress <i>Adam O’Riordan, Danielle A Young, Taryn E Cook, and Annie T Ginty</i>	285
Respiratory control and circuitry <i>Amy Amla Kartar and Alessandro Colasanti</i>	293
Gut–brain interactions <i>Michiko Kano and Shin Fukudo</i>	312
Brain control of bladder control <i>Rachel A High and Charles Mazeaud</i>	334
The sexual response <i>Janniko R Georgiadis</i>	341
Sudomotor function, thermoregulation and electrodermal control in the human brain <i>Laura Crucianelli, Gerardo Salvato, Yoko Nagai, Lisa Quadt, and Hugo Critchley</i>	357
Control of pupil responses <i>Siddhartha Joshi</i>	374
Sleep and sleep disorders <i>Maria P Mogavero, Giuseppe Lanza, Luigi Ferini Strambi, Lourdes M DelRosso, and Raffaele Ferri</i>	388
Epilepsy, breathing and bodily physiology <i>Toru Horinouchi, Alessandro Colasanti, and Yoko Nagai</i>	405
Vagus nerve and stimulation <i>Mahinda Yogarajah</i>	418
Autonomic biofeedback and the human brain <i>Yoko Nagai</i>	436

**Motor Processes**

Hand reaching: From motor control to intention and awareness <i>L Bardi, G Coudé, and M Desmurget</i>	446
Mapping cortical motor representations <i>Pierre-Aurélien Beuriat and Irene Cristofori</i>	462
Action representations and associated disorders <i>Elena Daprati and Daniele Nico</i>	476
Motor systems in developmental coordination disorder/dyspraxia <i>Alice Gomez and Caroline Huron</i>	486
Body awareness disorders after brain damage <i>Carlotta Fossataro, Alice Rossi Sebastiano, and Francesca Garbarini</i>	501
Cortical reorganization in the adult primary sensorimotor cortex <i>Sanne Kikkert, Victoria Root, Sarah Buehler, and Tamar R Makin</i>	516

**Sensory Processes**

Comparative retinotopic mapping in macaques and humans <i>Wim Vanduffel and Qi Zhu</i>	532
Cortical face processing systems <i>Galit Yovel, Bradley Duchaine, and Winrich Freiwald</i>	546
Pupil reactivity <i>Claire Wardak and Nadia Aguillon-Hernandez</i>	566
Visual-vestibular guided control of posture, movement and self-motion perception <i>Werner M Graf</i>	582
Space perception <i>Frank Bremmer</i>	612
The neural bases of visual attention <i>Suliann Ben Hamed and Timo van Kerkoerle</i>	627
The cerebral architecture of voice information processing <i>Pascal Belin</i>	642
Reciprocal interactions between the oxytocin and somatosensory systems <i>Stephanie Küppers, Arthur Lefevre, and Valery Grinevich</i>	649
Cortical control of eye movements <i>Olivia Rutler, Christopher Driscoll, Sarah E Stella, Serena Persaud, and Michael E Goldberg</i>	666
Neurophysiology of gaze orientation: Core neuronal networks <i>Laurent Goffart, Julie Quinet, and Clara Bourrelly</i>	681
Parieto-frontal circuits underlying motor and cognitive functions <i>Luca Bonini and Pier Francesco Ferrari</i>	700



This page intentionally left blank

## CONTRIBUTORS TO VOLUME 1

---

Nadia Aguillon-Hernandez

*Université de Tours, INSERM, Imaging Brain & Neuropsychiatry iBraiN U1253, Tours, France*

Harith Akram

*UCL Queen Square Institute of Neurology, The National Hospital for Neurology and Neurosurgery, London, United Kingdom*

Sheeba Anteraper

*Advanced Imaging Research Center, University of Texas Southwestern Medical Center, Dallas, TX, United States; and Department of Bioengineering, University of Illinois Urbana-Champaign, Champaign, IL, United States*

Somayeh Maleki Balajoo

*Institute of Neuroscience and Medicine, Brain and Behavior (INM-7), Research Centre Jülich, Germany; and Institute of Systems Neuroscience, Medical Faculty, Heinrich-Heine-University Düsseldorf, Germany*

L Bardi

*Institute of Cognitive Neuroscience Marc Jeannerod, CNRS/UMR, Bron, France; and Université Claude Bernard, Lyon 1, Lyon, France*

Pascal Belin

*Institut de Neurosciences de la Timone, CNRS & Aix-Marseille Université, Marseille, France*

Jacopo Bellomo

*Clinical Neuroscience Center, University of Zurich, Swiss Federal Institute of Technology Zurich, Zurich, Switzerland; and Department of Neurosurgery, University Hospital Zurich, Zurich, Switzerland*

Eduardo E Benarroch

*Mayo Clinic, Rochester, MN, United States*

Suliann Ben Hamed

*Institut des Sciences Cognitives Marc Jeannerod, CNRS UMR, Université Claude Bernard Lyon 1, Lyon, France*

Gary G Berntson

*Department of Psychology, The Ohio State University, Columbus, OH, United States*

Pierre-Aurélien Beuriat

*Institute of Cognitive Science Marc Jeannerod, CNRS/UMR 5229, Bron, France; Université Claude Bernard, Villeurbanne, France; Department of Pediatric Neurosurgery, Hôpital Femme Mère Enfant, Hospices Civils de Lyon, Lyon, France; and Rockefeller School of Medicine, Claude Bernard University, Lyon, France*

Asthik Biswas

*Department of Neuroradiology, Great Ormond Street Hospital for Children NHS Foundation Trust, London, United Kingdom*

Luca Bonini

*Department of Medicine and Surgery, Unit of Neuroscience, University of Parma, Parma, Italy*

Clara Bourselle

*University of Pittsburgh, Center for the Neural Basis of Cognition, Pittsburgh, PA, United States*

Frank Bremmer

*Department of Neurophysics, Philipps-Universität Marburg, Marburg, Germany; and Center for Mind, Brain and Behavior – CMBB, Philipps-Universität Marburg, Marburg, Justus-Liebig-Universität Gießen, Giessen and Technische Universität Darmstadt, Darmstadt, Germany*

Rachel M Brouwer

*Department of Complex Trait Genetics, Center for Neurogenomics and Cognitive Research, Vrije Universiteit Amsterdam, Amsterdam, the Netherlands*

Karl-Jürgen Bär

*Lab for Autonomic Neuroscience, Imaging and Cognition (LANIC), Department of Psychosomatic Medicine and Psychotherapy, Jena University Hospital, Jena, Germany*

Sarah Buehler

*Institute of Cognitive Neuroscience, University College London, London, United Kingdom*

Alessandro Colasanti

*Brighton and Sussex Medical School, Department of Neuroscience, University of Sussex, Brighton, United Kingdom; Sussex Partnership NHS Foundation Trust, Brighton, United Kingdom; and Department of Neuroscience Brighton and Sussex Medical School, University of Sussex, Sussex, Brighton, United Kingdom*

Taryn E Cook

*Department of Psychology and Neuroscience, Baylor Sciences Building, Baylor University, Waco, TX, United States*

G Coudé

*Institute of Cognitive Neuroscience Marc Jeannerod, CNRS/UMR, Bron, France; and Université Claude Bernard, Lyon 1, Lyon, France*

Irene Cristofori

*Institute of Cognitive Science Marc Jeannerod, CNRS/UMR 5229, Bron, France; and Université Claude Bernard, Villeurbanne, France*

Hugo Critchley

*Brighton and Sussex Medical School, University of Sussex, Brighton, United Kingdom; and Department of Clinical Neuroscience, Brighton and Sussex Medical School, Trafford Centre, University of Sussex, Brighton, United Kingdom*

Laura Crucianelli

*Department of Biological and Experimental Psychology, Queen Mary University of London, London, United Kingdom*

Elena Daprati

*Dipartimento di Medicina dei Sistemi & CBMS, Università di Roma Tor Vergata, Roma, Italy*

Feliberto de la Cruz

*Lab for Autonomic Neuroscience, Imaging and Cognition (LANIC), Department of Psychosomatic Medicine and Psychotherapy, Jena University Hospital, Jena, Germany*

Lourdes M DelRosso

*University of California San Francisco, Fresno, CA, United States*

M Desmurget

*Institute of Cognitive Neuroscience Marc Jeannerod, CNRS/UMR, Bron, France; and Université Claude Bernard, Lyon 1, Lyon, France*

Christopher Driscoll

*Columbia University, Institute of Human Nutrition, New York, NY, United States; and Columbia University, Mortimer B. Zuckerman Mind Brain Behavior Institute, New York, NY, United States*

Bradley Duchaine

*Psychological and Brain Sciences, Dartmouth College, Hanover, NH, United States*

Lilit Dulyan

*Donders Institute for Brain Cognition Behaviour, Radboud University, Nijmegen, the Netherlands; Max Planck Institute for Psycholinguistics, Nijmegen, the Netherlands; and Brain Connectivity and Behaviour Laboratory, Sorbonne Universities, Paris, France*

Kelly E Faig

*Department of Psychology, Hamilton College, Clinton, NY, United States*

Luigi Ferini Strambi

*Vita-Salute San Raffaele University, Milan, Italy; and Sleep Disorders Center, Division of Neuroscience, San Raffaele Scientific Institute, Milan, Italy*

Pier Francesco Ferrari

*Institut des Sciences Cognitives Marc Jeannerod, CNRS, Université de Lyon, Lyon, France*

Raffaele Ferri

*Sleep Research Center and Clinical Neurophysiology Research Unit, Oasi Research Institute - IRCCS, Troina, Italy*

Jorn Fierstra

*Clinical Neuroscience Center, University of Zurich, Swiss Federal Institute of Technology Zurich, Zurich, Switzerland; and Department of Neurosurgery, University Hospital Zurich, Zurich, Switzerland*

Stephanie J Forkel

*Donders Institute for Brain Cognition Behaviour, Radboud University, Nijmegen, the Netherlands; Max Planck Institute for Psycholinguistics, Nijmegen, the Netherlands; Brain Connectivity and Behaviour Laboratory, Sorbonne Universities, Paris, France; and Center for Neuroimaging Sciences, Department of Neuroimaging, Institute of Psychiatry, Psychology and Neuroscience, King's College London, London, United Kingdom*

Carlotta Fossataro

*MANIBUS Lab, Psychology Department, University of Turin, Turin, Italy*

Winrich Freiwald

*The Rockefeller University, New York, NY, United States*

Karl Friston

*The Wellcome Centre for Human Neuroimaging, UCL Queen Square Institute of Neurology, London, United Kingdom; and VERSES AI Research Lab, Los Angeles, CA, United States*

Shin Fukudo

*Department of Behavioral Medicine, Tohoku University Graduate School of Medicine, Sendai, Japan; and Department of Psychosomatic Medicine, Tohoku University Hospital, Sendai, Japan*

Francesca Garbarini

*MANIBUS Lab, Psychology Department, University of Turin, Turin, Italy; and NIT, Neuroscience Institute of Turin, Turin, Italy*

Sarah Garfinkel

*UCL Institute of Cognitive Neuroscience, London, United Kingdom*

Sarah Genon

*Institute of Neuroscience and Medicine, Brain and Behavior (INM-7), Research Centre Jülich, Germany; and Institute of Systems Neuroscience, Medical Faculty, Heinrich-Heine-University Düsseldorf, Germany*

Janniko R Georgiadis

*Department of Biomedical Sciences of Cells and Systems/ Section Anatomy & Medical Physiology, University of Groningen, University Medical Center Groningen (UMCG), Groningen, the Netherlands; and School of Medicine and Health Sciences, Carl von Ossietzky University Oldenburg, Oldenburg, Germany*

Annie T Ginty

*Department of Psychology and Neuroscience, Baylor Sciences Building, Baylor University, Waco, TX, United States*

Laurent Goffart

*Aix Marseille Université, CNRS, Institut de Neurosciences de la Timone, Marseille, France; and Aix Marseille Université, CNRS, Centre Gilles Gaston Granger, Aix-en-Provence, France*

Michael E Goldberg

*Columbia University, Mortimer B. Zuckerman Mind Brain Behavior Institute, New York, NY, United States; Columbia University Irving Medical Center, Department of Neurology, New York, NY, United States; and Departments of Neuroscience, Neurology, Psychiatry, and Ophthalmology, Columbia University College of Physicians and Surgeons, New York, NY, United States*

David S Goldstein

*Autonomic Medicine Section, Clinical Neurosciences Program, Division of Intramural Research, National Institute of Neurological Disorders and Stroke, National Institutes of Health, Bethesda, MD, United States*

Alice Gomez

*Institute of Cognitive Science Marc Jeannerod, UMR 5229, CNRS, University Claude Bernard Lyon I, Boulevard Pinel, Bron, France*

Werner M Graf

*Department of Physiology and Biophysics, Howard University College of Medicine, Washington DC, United States*

Valery Grinevich

*Department of Neuropeptide Research in Psychiatry, Central Institute of Mental Health, Medical Faculty Mannheim, University of Heidelberg, Mannheim, Germany*

Eva Guzmán Chacón

*Donders Institute for Brain Cognition Behaviour, Radboud University, Nijmegen, the Netherlands*

Luke A Henderson

*Brain and Mind Centre, University of Sydney, Sydney, NSW, Australia*

Rachel A High

*Division of Urogynecology, Houston Methodist Hospital, Houston, TX, United States*

Toru Horinouchi

*Department of Psychiatry and Neurology, Hokkaido University Hospital, Sapporo, Japan*

Caroline Huron

*Inserm U 1284, Centre de Recherche Interdisciplinaire, Université de Paris, Paris, France*

Agustín Ibáñez

*Latin American Brain Health Institute (BrainLat), Universidad Adolfo Ibáñez, Santiago, Chile; Cognitive Neuroscience Center (CNC), Universidad de San Andrés, Buenos Aires, Argentina; National Scientific and Technical Research Council (CONICET), Buenos Aires, Argentina; Global Brain Health Institute, University of California San Francisco (UCSF), San Francisco, CA, United States; and Trinity College Dublin, Dublin, Ireland*

Sebastian Ille

*Department of Neurosurgery; Heidelberg University Hospital, Ruprecht-Karls-University Heidelberg, Heidelberg, Germany*

Siddhartha Joshi

*Department of Neurosurgery, Stanford University, Stanford, CA, United States*

Michiko Kano

*Department of Behavioral Medicine, Tohoku University Graduate School of Medicine, Sendai, Japan; and Iwakiri Hospital, Sendai, Japan*

Amy Amla Kartar

*Brighton and Sussex Medical School, Department of Neuroscience, University of Sussex, Brighton, United Kingdom*

Jerillyn S Kent

*Department of Psychology, School of Behavioral and Brain Sciences, The University of Texas at Dallas, Richardson, TX, United States*

Sanne Kikkert

*Department for Health Sciences and Technology, ETH Zürich, Zürich, Switzerland*

Roxana N Kooijmans

*Netherlands Institute for Neuroscience, The Royal Netherlands Academy of Arts and Sciences, Amsterdam, the Netherlands; and INM-1, Institute for Neuroscience and Medicine, Forschungszentrum Jülich, Jülich, Germany*

Sandro M Krieg

*Department of Neurosurgery; Heidelberg University Hospital, Ruprecht-Karls-University Heidelberg, Heidelberg, Germany*

Stephanie Küppers

*Department of Neuropeptide Research in Psychiatry, Central Institute of Mental Health, Medical Faculty Mannheim, University of Heidelberg, Mannheim, Germany*

Maitreyee Kulkarni

*Department of Psychology, School of Behavioral and Brain Sciences, The University of Texas at Dallas, Richardson, TX, United States*

Giuseppe Lanza

*Sleep Research Center and Clinical Neurophysiology Research Unit, Oasi Research Institute - IRCCS, Troina, Italy; and Department of Surgery and Medical-Surgical Specialties, University of Catania, Catania, Italy*

Arthur Lefevre

*Department of Neuropeptide Research in Psychiatry, Central Institute of Mental Health, Medical Faculty Mannheim, University of Heidelberg, Mannheim, Germany*

Vaughan G Macefield

*Department of Neuroscience, Monash University, Melbourne, VIC, Australia*

Bernardo de APC Maciel

*Department of Complex Trait Genetics, Center for Neurogenomics and Cognitive Research, Vrije Universiteit Amsterdam, Amsterdam, the Netherlands*

Tamar R Makin

*Institute of Cognitive Neuroscience, University College London, London, United Kingdom*

Flavia Massey

*UCL Queen Square Institute of Neurology, The National Hospital for Neurology and Neurosurgery, London, United Kingdom*

Charles Mazeaud

*Department of Urology, Nancy University Hospital, France, IADI-UL-INSERM (U1254), Vandœuvre-lès-Nancy, France*

Joaquín Migeot

*Latin American Brain Health Institute (BrainLat), Universidad Adolfo Ibáñez, Santiago, Chile; and Center for Social and Cognitive Neuroscience (CSCN), School of Psychology, Universidad Adolfo Ibáñez, Santiago, Chile*

Maria P Mogavero

*Vita-Salute San Raffaele University, Milan, Italy; and Sleep Disorders Center, Division of Neuroscience, San Raffaele Scientific Institute, Milan, Italy*

Alberto Morello

*Department of Neurosurgery, CTO Hospital, Turin, Italy*

Yoko Nagai

*Department of Neuroscience, Brighton and Sussex Medical School, University of Sussex, Falmer, Brighton, United Kingdom; Department of Neuroscience Brighton and Sussex Medical School, University of Sussex, Sussex, Brighton, United Kingdom; Department of Psychology, Health and Medical Science, University of Surrey, Surrey, Guildford, United Kingdom; and Department of Clinical Neuroscience, Brighton and Sussex Medical School, Trafford Centre, University of Sussex, Brighton, United Kingdom*

Paul Naser

*Department of Neurosurgery, Heidelberg University Hospital, Heidelberg, Germany*

Daniele Nico

*Dipartimento di Psicologia, Università di Roma La Sapienza, Roma, Italy*

Greg J Norman

*Department of Psychology, The University of Chicago, Chicago, IL, United States*

Sebastian Ocklenburg

*Department of Psychology, Medical School Hamburg, Hamburg, Germany; ICAN Institute for Cognitive and Affective Neuroscience, Medical School Hamburg, Hamburg, Germany; and Institute of Cognitive Neuroscience, Department of Biopsychology, Faculty of Psychology, Ruhr University Bochum, Bochum, Germany*

Adam O’Riordan

*Department of Psychology and Neuroscience, Baylor Sciences Building, Baylor University, Waco, TX, United States*

Joel Patchitt

*Brighton and Sussex Medical School, University of Sussex, Brighton, United Kingdom*

Serena Persaud

*Columbia University, Institute of Human Nutrition, New York, NY, United States; and Columbia University, Mortimer B. Zuckerman Mind Brain Behavior Institute, New York, NY, United States*

Amedeo Piazza

*Department of Neurosurgery, Sapienza University, Rome, Italy*

Anna Plachti

*Institute of Systems Neuroscience, Medical Faculty, Heinrich-Heine-University Düsseldorf, Germany*

Lisa Quadt

*Department of Clinical Neuroscience, Brighton and Sussex Medical School, Trafford Centre, University of Sussex, Brighton, United Kingdom*

Julie Quinet

*Department of Optometry and Vision Science, University of Alabama at Birmingham, Birmingham, AL, United States*

Victoria Root

*Institute of Cognitive Neuroscience, University College London, London, United Kingdom; and FMRIB Centre, Nuffield Department of Clinical Neurosciences, University of Oxford, Oxford, United Kingdom*

Alice Rossi Sebastiano

*MANIBUS Lab, Psychology Department, University of Turin, Turin, Italy*

Olivia Rutler

*Columbia University, Institute of Human Nutrition, New York, NY, United States; and Columbia University, Mortimer B. Zuckerman Mind Brain Behavior Institute, New York, NY, United States*

Gerardo Salvato

*Department of Brain and Behavioral Sciences, University of Pavia, Pavia, Italy; Cognitive Neuropsychology Centre, ASST “Grande Ospedale Metropolitano Niguarda”, Milano, Italy; and NeuroMi, Milan Center for Neuroscience, Milano, Italy*

Tilman Schubert

*Clinical Neuroscience Center, University of Zurich, Swiss Federal Institute of Technology Zurich, Zurich, Switzerland; and Department of Neuroradiology, University Hospital Zurich, Zurich, Switzerland*

Andy Schumann

*Lab for Autonomic Neuroscience, Imaging and Cognition (LANIC), Department of Psychosomatic Medicine and Psychotherapy, Jena University Hospital, Jena, Germany*

Maximilian Schwendner

*Department of Neurosurgery; Heidelberg University Hospital, Ruprecht-Karls-University Heidelberg, Heidelberg, Germany*

Carlo Serra

*Clinical Neuroscience Center, University of Zurich, Swiss Federal Institute of Technology Zurich, Zurich, Switzerland; and Department of Neurosurgery, University Hospital Zurich, Zurich, Switzerland*

Antonio Spinello

*Department of Neurosurgery, Cantonal Hospital St.Gallen, St. Gallen, Switzerland*

Sarah E Stella

*Columbia University, Institute of Human Nutrition, New York, NY, United States; and Columbia University, Mortimer B. Zuckerman Mind Brain Behavior Institute, New York, NY, United States*

Bogdana Suchorska

*Department of Neurosurgery, Heidelberg University Hospital, Heidelberg, Germany*

Chatrin Suksasilp

*UCL Institute of Cognitive Neuroscience, London, United Kingdom*

Martijn van den Heuvel

*Department of Complex Trait Genetics, Center for Neurogenomics and Cognitive Research, Vrije Universiteit Amsterdam, Amsterdam, the Netherlands; and Department of Clinical Genetics, UMC Amsterdam, Amsterdam Neuroscience, Amsterdam, the Netherlands*

Wim Vanduffel

*Laboratory of Neuro- and Psychophysiology, Department of Neurosciences, KU Leuven, Leuven, Belgium; Leuven Brain Institute, KU Leuven, Leuven, Belgium; Athinoula A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital, Charlestown, MA, United States; and Department of Radiology, Harvard Medical School, Boston, MA, United States*

Timo van Kerkoerle

*Department of Neurophysics, Donders Centre for Neuroscience, Radboud University Nijmegen, Nijmegen, the Netherlands*

Thomas Visser

*Donders Institute for Brain, Cognition, and Behaviour, Radboud University, Nijmegen, the Netherlands*

Claire Wardak

*Université de Tours, INSERM, Imaging Brain & Neuropsychiatry iBraiN U1253, Tours, France*

Oi Yean Wong

*Department of Neuroradiology, Great Ormond Street Hospital for Children NHS Foundation Trust, London, United Kingdom*

Mahinda Yogarajah

*Department of Clinical & Experimental Epilepsy, UCL Queen Square Institute of Neurology, London, United Kingdom; Chalfont Centre for Epilepsy, London, United Kingdom; and NIHR University College London Hospitals Biomedical Research Centre, London, United Kingdom*

Danielle A Young

*Department of Psychology and Neuroscience, Baylor Sciences Building, Baylor University, Waco, TX, United States*

Galit Yovel

*School of Psychological Sciences, Sagol School of Neuroscience, Tel Aviv University, Tel Aviv, Israel*

Qi Zhu

*Laboratory of Neuro- and Psychophysiology, Department of Neurosciences, KU Leuven, Leuven, Belgium; and Cognitive Neuroimaging Unit, INSERM, CEA, Université Paris-Saclay, NeuroSpin Center, Gif/Yvette, France*

## EDITOR IN CHIEF

---

Jordan Grafman



**Jordan Grafman, PhD**, is the Director of Brain Injury Research at the Shirley Ryan Ability Lab and a Professor in the Department of Physical Medicine and Rehabilitation at the Feinberg School of Medicine at Northwestern University. His investigation of brain function and behavior has contributed to advances in medicine, rehabilitation, and psychology and informs ethics, law, philosophy, and health policy. His study of the human prefrontal cortex and cognitive neuroplasticity incorporates neuroimaging and genetics, an approach that is expanding our knowledge of the impact of traumatic brain injury (TBI), as well as other diseases that impair brain function, such as stroke and degenerative diseases. Dr. Grafman always aims to translate his research into more effective, targeted rehabilitation to achieve the best outcomes for people with cognitive disabilities. He has authored more than 500 research publications and recently retired as the co-editor of the journal *Cortex*. Prior to coming back home to Chicago, Dr. Grafman was in the intramural research program at the National Institutes of Health where he served as chief of the Cognitive Neuroscience Section at the National Institute of Neurological Disorders and Stroke and had the opportunity to mentor many outstanding postdoctoral fellows, research assistants, and students. Prior to joining the National Institutes of Health, Dr. Grafman served in the US Air Force and was assigned to the Walter Reed Army Medical Center as neuropsychology chief of the Vietnam Head Injury Study (VHIS), a long-term study of more than 500

soldiers with penetrating traumatic brain injuries suffered in combat. Dr. Grafman assumed leadership of the study since 1990. He is the world's leading expert on the long-term effects of penetrating brain injuries in military personnel. His expertise includes the scope of challenges faced during recovery, including behavioral changes like aggression, late sequelae such as seizures, the impact of TBI on the onset of late-life neurodegenerative disorders, and the impact on TBI on family life and employment, and legal implications. He has also studied depression, PTSD, and suicidal ideation in the Vietnam Veterans that have participated in the VHIS. He is an elected fellow of the American Psychological Association and the New York Academy of Sciences. Dr. Grafman is the recipient of many prestigious awards including the Department of Defense Meritorious Service Award, the National Institutes of Health Award of Merit, 2010 National Institutes of Health Director's Award, and the Humboldt Research Award from Germany. His expert opinion is often sought by national media on issues related to brain function and behavior, traumatic brain injury, cognitive rehabilitation, and policy and legal issues related to brain behavior research.



This page intentionally left blank

## SECTION EDITORS

---

### Markus Ullsperger



Professor Markus Ullsperger heads the Department of Neuropsychology at the Otto von Guericke University Magdeburg. His research focuses on developing and testing neurobiologically plausible models of performance monitoring and adaptive goal-directed behavior in humans. To this end, he pursues a convergent-methods approach combining neuroimaging and EEG with computational modeling and pharmacological challenges. In addition to studies in healthy participants, his research extends to clinical populations with neurological, neuropsychological, and psychiatric disorders. His current work focuses on the interactions of the anterior midcingulate cortex with other brain regions to signal the necessity and implement adaptations, ranging from motor slowing via shifts in selective attention to learning and belief updating.

Trained as a physician, Markus Ullsperger obtained his doctoral degree at the Max Planck Institute of Cognitive Neuroscience in Leipzig, Germany, in 2000. Thereafter, he worked as a scientific staff member at the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig at the Department of Cognitive Neurology. After his habilitation, he moved to Cologne, where he headed the Max Planck Research Group “Cognitive Neurology” at the Max Planck Institute for Neurological Research. In 2009, he was appointed as a Full Professor of Biological Psychology at the Radboud University Nijmegen, Netherlands, and a principal investigator at the Donders Institute for Brain, Cognition, and Behavior. Since 2012, he has been a Full professor of Neuropsychology at the Otto von Guericke University Magdeburg, Germany. Since 2017, he has been a member of the Board of Directors of the Center for Behavioral Brain Sciences Magdeburg. In 2021/22, he was elected President of the Society for Psychophysiological Research (SPR).

### Aron K. Barbey



Aron Keith Barbey is the Mildred Francis Thompson University Professor and the Director of the Center for Brain, Biology and Behavior, and the Decision Neuroscience Laboratory at the University of Nebraska-Lincoln. He began his career at the Beckman Institute for Advanced Science and Technology at the University of Illinois Urbana-Champaign in 2011, where he was promoted to Full Professor in 2019. Dr. Barbey’s research investigates the neural mechanisms of human intelligence and decision-making, with particular emphasis on enhancing these functions through cognitive neuroscience, physical fitness, and nutritional intervention. His research has been supported by the Office of the Director of National Intelligence, the Department of Defense, the White House BRAIN Initiative, the National Institutes of Health, the National Science Foundation, and private industry (Abbott Nutrition, Google Brain, and PepsiCo). Dr. Barbey has received multiple research awards and is the co-editor of the *Cambridge Handbook of Intelligence and Cognitive Neuroscience* and the editor of the forthcoming *Oxford Handbook of Cognitive Enhancement and Brain Plasticity*. In 2023, Dr. Barbey was appointed to the United States Defense Science Study Group at the Institute for Defense Analyses. He earned his doctorate in Psychology from Emory University and completed a research fellowship in Cognitive Neuroscience at the National Institutes of Health.

**Keith McGregor**

Keith McGregor is a Health Research Scientist at the Birmingham VA Geriatrics Research Education and Clinical Center (GRECC) and an Associate Professor in the Department of Clinical and Diagnostic Sciences at the University of Alabama at Birmingham. His work investigates aging-related declines in motor control and its implications for stroke rehabilitation.

**Graduate Student acknowledgments:**

Bryana Whitaker-Hardin, Graduate Biomedical Sciences, UAB School of Medicine  
Ashton Weber, Neuroengineering Program, UAB School of Engineering  
Ayat Najmi, Rehabilitation Sciences, UAB School of Health Professions  
Sarah Katherine Sweatt, Nutrition Science, UAB School of Health Professions

**Hugo Critchley**

Hugo Critchley is Professor of Psychiatry at Brighton and Sussex Medical School (BSMS). He works clinically as a neuropsychiatrist at the Neurodevelopmental Services that he helped set up in 2006 in Sussex Partnership NHS Foundation Trust. His research focuses on brain mechanisms supporting normal and abnormal emotion, with particular emphasis on bidirectional brain-body interactions. The work encompasses the basic and clinical investigation of emotions, autonomic control, interoception and their contributions to neurodivergence, psychological symptoms, and mental illness and its impact on mental health and physical. He has been funded by Research Councils including an advanced grant from the European Research Council and charities including MQ, have helped develop careers of leading clinical scientists.

Hugo graduated in Physiology and Medicine at the University of Liverpool before completing a Doctorate in Psychological Studies at the University of Oxford. He is trained in psychiatry and clinical neuroscience at the Kings College London Institute of Psychiatry and at the University College London (UCL) Institute of Neurology where he integrated autonomic medicine within his research programme. At the KCL, he developed an integrative research programme through competitive funding including Clinician Scientist and Senior Clinical Fellowships from the Wellcome Trust. He held appointments as Consultant in Neuropsychiatry at the National Hospital UCLH, Principal at the Wellcome Department of Imaging Neuroscience, and Group Leader at the UCL Institute of Cognitive Neuroscience.

In 2006, Hugo moved to the University of Sussex as foundation Professor of Psychiatry at the (then new) Brighton and Sussex Medical School. He built a research group and Department of Clinical Neuroscience, which he headed until 2023, and was a founding co-director of the Centre for Consciousness Science 2010-2022. He was Chair of the Academic Faculty of the Royal College of Psychiatrists from 2019-2024 (and as vice chair 2015-2019). He works passionately to help improve career paths and stem the depletion of the Academic Psychiatry workforce across the UK nations. In 2010, He was a founding co-director of the Centre for Consciousness Science at the University of Sussex and Head of BSMS Department of Clinical Neuroscience until 2023.

**Michael Borich**

Dr. Michael Borich, DPT, PhD, is an Associate Professor in the Division of Physical Therapy, Department of Rehabilitation Medicine in the Emory University School of Medicine. He is also the Vice-Chair of Research for the department. He has a secondary appointment in the Wallace H. Coulter Department of Biomedical Engineering, a joint Emory/Georgia Tech department, and is a faculty member of Neuroscience Graduate Program at Emory. He received his Bachelor's degree in Physiology and Doctor of Physical Therapy, along with a PhD in Rehabilitation Science and Neuroscience from the University of Minnesota. He then completed his postdoctoral training at the University of British Columbia with Dr. Lara Boyd prior to his arrival at Emory and Georgia Tech.

Dr. Borich is keenly interested in understanding and exploiting the plastic capacity of the human nervous system in health and disease to improve rehabilitation outcomes for individuals with neurologic injury and disease. The Neural Plasticity Research Lab at Emory, directed by Dr. Borich, is a transdisciplinary research and training environment generously supported by multiple funding agencies. He also codirects the Precision Neural Engineering Laboratory at Emory aiming to understand neural mechanisms of sensorimotor control. His labs emphasize collaborative research in an inclusive training environment. His team utilizes multimodal neuroimaging and neurostimulation techniques

to characterize and modulate the structural and functional neuroplastic correlates of learning and experience. The mission of his work is to understand and harness the adaptive capacity of human nervous system to develop effective treatment strategies to improve rehabilitation outcomes and maximize healthy years in the lifespan.

**Scott Grafton**

Scott Grafton received a BA in Mathematics and Psychobiology at the University of California at Santa Cruz in 1980 and an MD at University of Southern California (USC) in 1984. He completed residencies in Neurology at University of Washington (1988) and Nuclear Medicine at UCLA (1990). He acquired expertise in functional imaging using positron emission tomography and magnetic resonance imaging while a Research Fellow at UCLA. He developed brain imaging programs in the Schools of Medicine at USC, Emory University and Dartmouth College before joining the faculty at UCSB in 2006, where he directs the UCSB Brain Imaging Center, is a Consulting Neurologist at UCSB, and a Distinguished Professor of Brain Science. He oversees an interdisciplinary research team that uses magnetic resonance imaging to understand how the brain changes as a healthy person acquires physical skills, makes decisions, and plans action. The imaging methods are also used to understand how the brain responds and recovers from injuries such as concussion and stroke or from neurologic diseases such as Parkinson's disease. He is the author of more than 270 scientific papers and a book for the general readership titled, *Physical Intelligence*.

**Jean-René Duhamel**

Jean-René Duhamel is a Neuroscientist known for his research on cognitive functions in primates. His work has contributed to our understanding of how the brain processes sensory information and supports higher cognitive functions such as attention, perception, and decision-making. He has conducted influential studies involving neurophysiological recordings from the brains of nonhuman primates, helping to map the neural circuits involved in these processes. His research often intersects with fields like psychology, neurology, and cognitive science.

Chad E. Forbes



Chad E. Forbes, PhD, is a Social Neuroscientist and an Associate Professor of Psychology at Florida Atlantic University (FAU). He is also the Associate Director for the FAU Brain Institute and a Fellow in the FAU HEALTH Institute and the National Center for Institutional Diversity at the University of Michigan among other affiliations. As a first-generation college student, he earned his Bachelor's in Psychology (minors in Biology and Chemistry) from Long Beach State University, followed by his doctorate degree in Psychology with emphases in social and cognitive neuroscience from the University of Arizona. Dr. Forbes also completed postdoctoral training at NIH in the Cognitive Neuroscience Section at the National Institute of Neurological Disorders and Stroke and the National Institute of Biomedical Imaging and Bioengineering. Broadly, his research examines the dynamic modulation of self and identity as a function of biology, memory, emotion, and time. Further, he examines how these processes are altered vis-a-vis the consequences of prejudice and implicit bias on, among other things, stigmatized individuals' career aspirations, and physical and mental health. This work has resulted in a number of federally funded grants and publications in a variety of top-tier journals in the field, including *Annual Reviews of Neuroscience* and the *Journal of Personality and Social Psychology*, and recognition from the American Psychological Association as a "Rising Star" in psychology.

Caitlin A. Orsini



Dr. Orsini received her BS in Psychology with a Behavioral Neuroscience concentration from Washington College in Chestertown, MD, after which she began graduate training in the Biopsychology division of the Department of Psychology at the University of Michigan in Ann Arbor. During her graduate training, Dr. Orsini's research centered on elucidating the neural circuitry that mediates the persistence of fear memories after extinction learning, with a particular focus on interactions between the basolateral amygdala, ventral hippocampus and prefrontal cortex. After receiving an MS and PhD from the University of Michigan, Dr. Orsini began a postdoctoral fellowship at the University of Florida, where she explored whether these same circuits involved in pathological fear are also recruited during active choice behaviors and whether similar dysfunction in these structures and pathways underlies maladaptive decision-making associated with substance use. As an Assistant Professor in the Department of Psychology at UT Austin, her research continues to focus on uncovering how neural mechanisms that normally govern adaptive decision-making become compromised in pathological conditions, including substance use and post-traumatic stress disorders. In addition, Dr. Orsini's lab tackles the question of how gonadal hormones regulate different forms of decision-making and whether dysfunction in this regulation also contributes to deficits in decision-making in psychiatric diseases.

Jean-Claude Dreher



Dr. Jean-Claude Dreher is currently a Research Director at the Institute of Cognitive Science in Lyon, France (<https://dreherteam.wixsite.com/neuroeconomics>). He is the head of the Neuroeconomics lab. He edited two books at Academic Press (*Reward and Decision Making* and *Decision Neuroscience*). He has served as the President of the Integrative Neuroscience committee at the ANR (National research agency). Dr. Dreher has received prestigious prizes and awards for his career, including the EURIAS award, the IBRO/UNESCO Science of Learning fellowship and the price "Eloi Collery" from the French National Academy of Medicine. After studying mathematics and graduating with distinction from University of Paris-Sorbonne University in Cognitive Neuroscience, he performed postdoctoral researches on reward processing and decision making at the National Institutes of Health (NINDS and NIMH), Bethesda, USA. His researches concern the neurocomputational mechanisms underlying decision making, motivation and reward processing in humans. His goals are to understand the functional organization of the prefrontal cortex in humans, the various functions that the reward dopaminergic system exerts on cognition and motivation and the neural mechanisms underlying dysfunctions of these brain systems in patients with psychiatric or neurological disorders. His current interests concern the computational characterization of social representations and the neurocomputational mechanisms engaged in moral decision making.

computational characterization of making.

**Angela Sirigu**

Angela Sirigu is a Distinguished Italian Neuroscientist recognized for her groundbreaking contributions to cognitive neuroscience and neuropsychology. She was the Director of the *Institut des Sciences Cognitives Marc Jeannerod* in Lyon, France, from 2016 to 2020. She heads a research group studying the neural mechanisms underlying social behavior, decision-making, and free will. Sirigu's research on oxytocin's role in social bonding and behavior has significantly advanced the field of social neuroscience. Her studies on how brain injuries affect behavior have led to innovative treatments for neurological disorders. Her prolific work is widely published and has earned her international recognition.

**Arne Ekstrom**

Dr. Arne Ekstrom's work focuses on human memory, with a particular focus on spatial navigation. Navigation is a fundamental skill for our everyday life, yet we lack an understanding of the brain mechanisms underlying this important function, particularly in humans. Dr. Ekstrom's research combines virtual reality and cutting edge brain recording techniques such as intracranial recordings in patients and wireless scalp EEG in freely moving subjects. Dr. Ekstrom's work has advanced the idea that navigation depends on a network of interacting brain regions, an important theme of this section. This section carefully works through single cell recordings, lesion, and behavioral findings in rats, monkeys, and humans, allowing the reader to see both the commonalities and differences between species.

**Lewis A. Wheaton**

Dr. Lewis A. Wheaton is a Professor in the School of Biological Sciences and the Director of the Cognitive Motor Control Lab and Director, Center for Promoting Inclusion and Equity in the Sciences, College of Sciences at Georgia Tech. Under Dr. Wheaton's direction, the Cognitive Motor Control lab at Georgia Tech seeks to understand neurophysiology guiding neuroplasticity and motor rehabilitation following upper limb amputation and stroke. This work involves utilizing human brain imaging, kinematics, behavior, and gaze tracking to understand perceptual-motor relationships. He received his PhD in Neuroscience and Cognitive Sciences from the University of Maryland, College Park in 2005, training as a research fellow at the National Institutes of Health (2001–2005) studying neural function and recovery of motor control after neurological injury. He conducted his post-doctoral fellowship at the Baltimore Veterans Affairs Medical Center (2005–2008) studying aging and stroke motor control in Veterans. He presently serves on the Executive Board of the American Society for Neurorehabilitation.

## Audrey L. Duarte



Dr. Duarte received her PhD in Neurobiology in 2004 from UC Berkeley. She was a Postdoctoral Fellow at the Medical Research Council Cognition and Brain Sciences Unit in Cambridge, UK, prior to joining the faculty in the School of Psychology at Georgia Tech between 2008 and 2021. She has been a Professor of Psychology and Neurology at UT Austin since 2021. She uses multiple, complementary, neuroimaging methods, including electroencephalography (EEG), functional magnetic resonance imaging (fMRI), and neuropsychology to investigate neural changes underlying age-related episodic memory decline across the adult lifespan. She and her lab study the role of malleable factors including sleep quality and depressive symptomology, and social determinants of health (e.g., discrimination stress, social support) as mediators and moderators of individual differences in memory impairment, associated neural activity, and memory decline. She has served as an Editor in Chief for the journal *Aging, Neuropsychology, and Cognition* and as an editor of *Neuroimage* and currently *Imaging Neuroscience*. She is a Fellow of the Psychonomic Society and received the Psychonomic Society Mid-Career Award in 2024.

## Larry Cahill



Dr. Larry Cahill is a Professor in the Department of Neurobiology and Behavior at the University of California, Irvine. He first became interested in brain and memory as an undergraduate at Northwestern University. After working for 2 years at Searle Drug Company in Illinois on memory enhancing drugs, he earned his PhD in Neuroscience from the University of California at Irvine in 1990 and then conducted postdoctoral research in Germany for 2 years. He returned to UC Irvine to extend his research to studies of human subjects, which in turn led to his discoveries about sex influences on emotional memory, and to his current general interest in the profoundly important topic of sex influences on brain and body function.

He is among the world leaders on the topic of sex influences on the brain. In 2017, he edited the first issue of any neuroscience journal devoted to the topic (a 70 paper, permanently open-access issue of *The Journal of Neuroscience Research*). He was instrumental in the 2016 adoption by the NIH of the landmark Sex as a Biological Variable (SABV) policy mandating consideration of sex influences in all NIH funded research. His current research interest focuses on the culturally important, but strikingly under-explored question of how hormonal contraception alters the developing adolescent female brain. He is among the top 2% of all scientists in terms of how much his work is cited. An

internationally regarded investigator and speaker, his work has been highlighted often in the press, including in the *New York Times*, *London Times*, *Washington Post*, *Frankfurter Allgemeine Zeitung*, *PBS*, *CNN*, and *60 Minutes*.

## Stephanie Forkel



Dr. Stephanie Forkel is a Principal Investigator and Research Group Leader for Clinical Neuroanatomy at the Donders Institute, an Associate Professor of Psycholinguistics at Radboud University, and a Senior Research Associate at the Max Planck Institute in the Netherlands. As the leader of the Language and Communication Theme, she has garnered recognition for her work, including winning the prestigious Elizabeth Warrington Prize for her contributions to neuroanatomy and cognition. Currently serving as the Organization of Human Brain Mapping OHBM Program Chair, Dr. Forkel's research focuses on neurovariability and its impact on cognition across different brain states, both in health and disease. Her work aims to deepen our understanding of shared and unique neural characteristics, ultimately transforming approaches to neurological diagnostics, predictions, and treatments, and advancing the field of precision neuroscience.

**Jeffrey R. Binder**

Jeffrey R. Binder is a Professor of Neurology and Biophysics at the Medical College of Wisconsin, Milwaukee, WI. His research focuses on the neurobiology of language and aphasia, with particular emphasis on speech perception systems, semantic memory and concept representation, visual word recognition, and presurgical language mapping. He received his medical degree at the University of Nebraska, followed by neurology training at the Columbia University Neurological Institute in New York. Binder established the MCW Language Imaging Laboratory in 1992, which has conducted extensive research on the neurobiology of language and aphasia using fMRI, MEG, and lesion-symptom mapping, and has been continuously funded by the NIH for over 30 years. In addition to his work on basic language neurobiology, Binder was principal investigator on the multi-center fMRI in Anterior Temporal Epilepsy Surgery (FATES) study and the Epilepsy Connectome Project, and he maintains a clinical practice focused on aphasia diagnosis and treatment. He is the recipient of a Distinguished Career Award from the Society for the Neurobiology of Language.

**A.M. Barrett**

Dr. A.M. Barrett is a Clinician-Scientist, with special expertise in both cognitive neurology and neuro-rehabilitation. Before taking her current role as CVNR Executive Director, she was the Director of Stroke Rehabilitation Research at the Kessler Foundation, and before that, was at Penn State College of Medicine. She brings together training in cognitive neurology and neuropsychology (the University of Florida, postdoctoral fellowship), Neurology (Columbia/The Neurologic Institute, residency) medicine (NYU School of Medicine, MD), and Brain Injury Medicine (ABPN certification). She completed an AB at Harvard/Radcliffe in Psychology and Social Relations and is a Fellow of the American Academy of Neurology, the American Neurological Association, and the American Society of Neurorehabilitation. Her research interests are in brain-behavior relationships relevant to spatial cognition and rehabilitation of spatial neglect; person-centered care and outcomes relevant to function and life participation; identification and management of hidden disabilities and mechanisms of deficit unawareness.

**Branch Coslett**

Dr. H Branch Coslett is a Neurologist in Philadelphia, Pennsylvania, and is affiliated with multiple hospitals in the area, including Good Shepherd Penn Partners Hospital and Hospitals of the University of Pennsylvania-Penn Presbyterian. He received his medical degree from Perelman School of Medicine at the University of Pennsylvania and has been in practice for more than 20 years. Dr. H Branch Coslett has expertise in treating non-Alzheimer's dementia, Alzheimer's dementia, among other conditions.



**Charan Ranganath**

Charan Ranganath is an Affiliated Faculty with the UC Davis Center for Neuroscience, which seeks to understand the function of the human brain in health and in illness. He is also the Director of the Dynamic Memory Lab at UC Davis and is an Affiliated Faculty with the Center for Mind and Brain. His research involves the use of functional neuroimaging, electrophysiology, and behavioral methods to study the neural basis of human memory and executive control. He previously served as an editor for the Cognitive Neuroscience Section of the journal *NeuroImage*, and currently serves as an editor for the *Journal of Neuroscience*, which is the most influential academically edited journal in the field of neuroscience. Professor Ranganath has consulted government and private funding agencies from several countries and has served on review panels for the National Institutes of Health and National Science Foundation.

His research concerns the neurocognitive structure of human memory and executive control. One set of studies currently underway concerns the relationship between short-term, or working memory, and long-term memory. Results from event-related fMRI studies conducted by Professor Ranganath suggest that overlapping regions of the prefrontal cortex and medial temporal lobes are active during both working memory and long-term memory tasks. This research suggests that a common neural system supports both of these types of memory. Currently, Professor Ranganath is investigating how different regions within the prefrontal cortex and medial temporal lobes contribute to working and long-term memory through additional fMRI studies of healthy young adults and behavioral testing of patients with focal brain damage. A second, related area of interest is the role of prefrontal cortex in the control and evaluation of information in memory.

**Rainer Goebel**

Rainer Goebel is driven by the question of how the human brain works, how it creates our mind, and how gained knowledge can be applied to the benefit of society. He has continuously transformed three fields: brain imaging of perception and cognition, neuroimaging analysis methods, and hemodynamic brain-computer interfaces (BCIs). In order to gain increasingly fine-grained insights on the neural basis of the human mind, he constantly develops new methods and pushes the limits of the achievable spatial resolution using ultra-high field (7 and 9.4 Tesla) fMRI scanners. He uses his gained insights and methodological expertise to develop innovative BCIs. His software enables, for example, letter spelling in motor-impaired patients using only brain activity data, and he has established a novel therapeutic approach that enables patients suffering from depression or Parkinson's disease to treat themselves using feedback of fMRI data from their own brains. During his career, Goebel acquired expertise in brain anatomy and function, fMRI scanning and data analysis, fNIRS data analysis, combined EEG/MEG/fMRI modeling, structural and functional connectivity modeling, TMS neuronavigation, neural network modeling, psychophysics and (clinical) brain-computer interfaces. He trained more than 60 PhD students contributing to the early career of many excellent researchers.

## PREFACE

---

Welcome to the *Encyclopedia of the Human Brain*! Fasten your intellectual seat belt. There is a lot to learn. Our brain allows us to interact with the world in simple and nuanced ways and is responsible for memories, our ability to speak and understand language, movements, sensations, identity, foresight and more. Happily, our team of Section Editors has recruited for your reading pleasure leading experts whose chapters contained in the *Encyclopedia of the Human Brain* will give you an updated view of the status of knowledge about the human brain. We are the rare species that can examine its own existence, and this Encyclopedia is an example of that. Our behaviors including self-examination, for the most part, depend upon the brain, and now we have increasingly sophisticated techniques that can measure and interpret brain activity using techniques such as neuroimaging, electrophysiology, and noninvasive brain stimulation in combination with sensorimotor, cognitive, social, and emotional tasks. These techniques can be applied with healthy volunteers, patients, and can even be utilized to improve communicative abilities in people who are otherwise unable to communicate because of trauma or a neurodegenerative disorder. The Encyclopedia includes chapters on all these techniques and topics.

The human brain is our inner universe. Everything we do or want to learn about from astrophysics to riding a bicycle to finding a partner or joining a social group requires our brain. Whew, that is some job. It is true that nowadays, using our brains, we are porting some of those responsibilities to devices that incorporate reinforcement learning and deep language models, but those computational processes still require input from the internet or humans. So, until we manufacture robots that can populate the world so that their recorded experiences and creativity become embedded in some global cloud-based server, our own brains remain the workhorse of inventive thinking and necessary to examine.

The second edition of the *Encyclopedia of the Human Brain* is more than double the size of the first edition, and that expansion reflects the exciting and impressive increase in human brain research over the last three decades. The Encyclopedia was designed to be a one-stop introduction for students and laypeople to the human brain, but since the entries are up-to-date and written by acknowledged experts, it can also be a place for academic researchers and clinical practitioners to go to find the latest information on a particular aspect of the human brain. *Human* brain research does not stand alone, and many of the chapters will describe how the human research they are reporting on is built upon studies in other species ranging from other primates, dolphins, and dogs to rodents.

I owe a debt of gratitude to the outstanding Section Editors who took on the task of recruiting experts in their domain to write chapters for the Encyclopedia and to the Elsevier editors who made my role rather easy to fulfill. Our brains are a treasure to behold at all ages. So, the *Encyclopedia of the Human Brain* is for neuroscience treasure hunters. Perhaps you will find that nugget that will motivate you to contribute, like so many others have, to knowledge about this remarkable organ.